AN APPROACH TO MARGINAL ANALYSIS

by

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This thesis developed a pragmatic approach to the optimization of business decisions in the chloralkali industry utilizing basic marginal analysis concepts. It attempted to meld accounting principles and techniques with economic concepts for the purpose of establishing a rationale and a workable model for guiding and evaluating everyday business decisions. The approach concentrated on short run decision making and did not get involved with capital and other variables which were fixed in the short run.

Many attempts to apply marginal analysis to the real world have had only limited success. The concepts as outlined in this thesis used a particular empirical example to circumvent some of the inherent difficulties associated with marginal analysis. The emphasis in this study was to develop a useful business tool and not to fit theoretical economic concepts into the real world.

The special requirements for this model were a capital intensive multiproduct company with a vertically integrated production line. Each product manufactured should have two outlets; a) to be used as raw materials to upgrade the product by further processing, or b) to be sold in the market place. Consequently, the product lines will be developed from relatively few raw materials. This is the situation in most petrochemical and inorganic chemical plants, oil refineries, and could even be applied to entire industries such as forest
products, and pulp and paper. Although the chloralkali model's construction were discussed, the model itself was not included in the thesis. The particular model used was large and complex, specially adapted for the firm, and as a result contained confidential information and relationships which were difficult to disguise. The empirical example assisted in the development of the essential concepts but did little to contribute to the proving of the hypothesis.
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CHAPTER I
INTRODUCTION

The advent of computer technology has developed an era of professional managers by expanding the information horizon and helping find relevant data for modern decision making techniques. Prior to this era, the purveyors of most financial information, the accountants, were not concerned with information for decision making outside the financial realm. Consequently many marketing and non-financial type decisions were either based on financial input or made in an intuitive manner. On the other hand, economists have been concerned with the development of economic theory without being completely successful in applying these theories to management decision making. The objective of this paper is to provide the business manager with a basis for making sounder decisions using more relevant data. This has been accomplished in a particular situation by melding accounting techniques and economic concepts into a workable model.

Basically, the thesis revolves around use of cost analysis in decision making for the optimization of profits. The approach has been to develop cost concepts in a marginal analysis framework, and in so doing, touch upon many other related problems associated with marginal analysis. Demand and cost have been analyzed under special conditions and constraints to provide an optimal way of choosing a marketing plan where profit is the goal. Most spatial, distributional, and legal considerations have been ignored as they do not affect the basic concepts and only add to the complexity of the analysis.
I. BACKGROUND SETTING FOR THE PROBLEM

The increasing pace and complexity of business in the modern world is placing increased decision making demands on today's manager. Technology and consumer demand have escalated this pace by mass production innovations and computer technology. With the rising costs of research and development, and the new competitive pressures, executives cannot afford incorrect decisions. When business was slower and less complex, our antiquated pen and quill statistical record keeping and slow painstaking analytical techniques sufficed. In addition, when mistakes were made, it was usually possible for the manager to react quickly and recover with minimal damage. The emphasis on profit was dollars in, less dollars out, equals profit. Consequently if dollars out were analyzed and controlled, and dollars in were maximized, profit would be optimized.

The era of computers made it possible to add, subtract, collate and analyze with precision more quickly and in greater detail. The analysis was initially only successful in producing large volumes of reports, most of which were poorly used, and many computer operators appeared to measure the success of their work by report volume and length. From an exposure to several computer oriented companies, and their system's analysts, for the past seven years, the author has deduced that most reports are designed by computer trained people and not by the operating managers. Consequently, many reports contain an abundance of incorrect, unreliable, and unsuitable information, and as such as often filed unused by the people who make the decisions. There were examples of reports produced
weekly that contained information that was "nice to know" but served no useful purpose and once the relationships were "known" the remaining weekly reports were redundant. Of all the departments in a corporation, this situation applies most specifically to the marketing personnel, who presumably give overall guidance to a company operating in today's competitive market place. To the computer data bank, sophisticated linear programs, risk analyses, discounted cash flow, return on investment, and other analytical programs were added to lend credence to investment decisions. Nevertheless, executives were still wondering how to optimize today's profitability in the market place within the constraints of the corporation and the existing facilities. These psuedo analyses and computer complications only seemed to drive managers further towards an intuitive approach. However, accountants and financial analysts using historical financial statistics were still able to evaluate performance, but unable to give guidance.

Economic theories can suggest theoretical concepts for profit optimization. One concept often explored in the literature is marginal analysis. This technique determines the condition for maximum economic profit by equating marginal revenues to marginal costs and solving for the level of output. The many attempts at marginal analysis have made substantial contributions to the analytical technique, but none have achieved a complete and workable methodology.

The problems with marginal analysis were often associated with miscellaneous input data; definitions and determination of marginal
revenues and marginal costs, the interpretation of economic profit, and its relationship to the profit and loss statement. Using sections of previous studies and a pragmatic approach to marginal analysis, this thesis has integrated economic theories and accounting techniques into a workable model to provide a meaningful approach to profit management and planning. The model has proposed a technique for generating and analyzing information to guide profit optimization decisions in the short run. As long run optimization and equilibrium is never likely to be achieved in any firm or industry, the analysis concentrated for practical purposes on the short run only.

II. PREVIOUS INVESTIGATIONS

Other investigations have pragmatically utilized the marginal analysis concept. The major contributor to the development of a workable technique has been J. Johnson.\(^1\) His often quoted and almost classical analysis "Cost output variations in a multiple product firm" is perhaps the best known. Several other writers\(^2\) who have updated the methodology such as Nancy Ruggles, Joel Dean, B. F. Beckwith, plus Andrews, J. R. Nelson, and others have also made significant contributions to the approach.

III. METHODOLOGY AND SOURCES OF DATA

The general plan of attack has been to explore the concepts of alternate value, opportunity cost, costs in general, and economic versus financial profits in a chloralkali situation analysis. The peculiarity


\(^2\)See Bibliography.
of the empirical case under study enabled the model to circumvent some of the short comings and difficulties of earlier studies. Shortcomings and peculiarities have been discussed at length both conceptually and during the analysis of the empirical model. The next step was fitting those concepts into a marginal analysis framework or optimizing model. In addition objections to the application of marginal analysis to decision making and the model were discussed. Overall concepts were supported by references to other studies and writers, although the essence of the technique was found in the selection of the empirical model. All details and statistical information was supplied through the company being studied.

IV. LIMITATIONS TO THE STUDY

Perhaps the most apparent limitation of the study was the lack of supportive statistical data, however, a complete review of the model and output data demonstrated that this confidential statistical information did not sufficiently support or lend credence to the study to warrant its inclusion. The complexity of the details in the model only obscured the conceptual approach, which is the theme of the thesis. Unfortunately the study and testing of only one empirical example does not allow a full definition or support all requirements for a successful analysis under various conditions and therefore application of the approach must be reserved. Many conclusions out of necessity will be general in nature and as such subject to criticism and revision.
The subject of profit optimization and planning is complex by nature and this approach is no panacea to its simplification. Only one economic theory has been exploited in a very narrow sector of business. There have been many approximations and assumptions made, some of which can be overcome with more complete and precise data and some by a more elaborate computer simulation. The analytical technique is only one of many for use as guides to profit optimization, but this approach can also measure the profit impact of decisions before implementation. This profit optimizing concept applies primarily to the marketing of a company's output; although plant scheduling is determined by the model, it does not indicate optimization of maintenance schedules, purchasing, or plant operation in a least cost manner. Objectives of the corporation and various operating departments have not been included, as profit optimization was the primary objective. Their exclusion from the analysis is not a serious limitation because the impact on profit of these other objectives can be determined separably in the model. The desirability of pursuing those objectives can then be assessed in terms of sacrificed profitability versus the other benefits accrued.

V. PREVIEW OF CHAPTER TOPICS

Chapter two explores the basic concepts associated with the model, touching upon the economic versus traditional accounting approaches to profit management. The theoretical structure of the model is developed, supported, and readied for integration with the empirical example. All relationships between critical elements in the model are analyzed and
assessed in importance. From these relationships the definitions used in the study are developed. Implications of the relationships, definitions, and concepts are discussed and a hypothesis derived. Chapter three the empirical setting, describes characteristics of the company, which are pertinent to the issues being covered, such as corporate background and objectives, product nature and assortment and market opportunities.

Chapter four integrates the framework of the basic concepts to the empirical setting and analyzes the resultant. The hypothesis is then reintroduced and a statement of substantiation or rejection made. Chapter five, the last chapter, contains a reiteration of major findings and presents the conclusions drawn from them. Hopefully it has also touched upon the many unsolved related problems and made recommendations for further research.
CHAPTER II

BASIC CONCEPTS

I. INTRODUCTION

In dynamic marketing situations, profit should be a determining guide for selecting from the various marketing policies, a strategy or program to achieve the corporate profit objective. This chapter has established the basic concepts for a methodology utilizing profit to guide profit optimizing decision making. Traditionally accountants have been the record keepers of historical explicit costs and revenues, providing the only statistics to guide the manager, but today the economists are suggesting alternative approaches. "Although economists and accountants agree that company profit is equal to income minus costs, they sometimes differ as to which costs should be deducted in computing profit". ¹ Prior to a discussion on the methodology for optimizing business profits, the economists methods for calculating profit must be demonstrated to be realistic and desirable. This chapter, however, has not been an attempt to disprove or discredit the traditional techniques used by accountants, as they have obviously been used with success around the world.

As profit is equal to revenue minus costs, a manager requires an intimate knowledge of revenue and cost analysis. Revenue is generally readily determined, but costs can be much more elusive. Although many differences exist the accountants and the economists definitions and determination of revenue are often sufficiently similar to be used interchangeably in this analysis. The accountant's approach to the determination of costs are pragmatic whereas the economists remain rather idealistic. One of the economists' theoretical approaches for guiding profit optimizing decisions has been marginal analysis. This means that a profit is maximized whenever the business is operated at a point where the marginal costs equal the marginal revenue and the total cost curve intersects the total revenue curve from below. When this analytical technique is used, the calculation of marginal costs and revenues are usually complex and difficult. Although the equating of marginal revenue to marginal cost is an abstract theory and usually only used to help understand the real world, in this thesis it does have pragmatic importance. However, before turning to this optimization technique the inherent problems associated with the uses of the economist's definitions of costs and revenues must be overcome or rationalized.

One such difficulty has been the economist's insistence on the use of opportunity costs at all times rather than historical explicit costs. The economist defines costs of production as the value of all foregone alternative products, which resources used in its production could have produced and not merely the sum of cash paid for these resources.²

One of the hypotheses of this thesis is that by careful definition most of the inherent difficulties could be overcome and a meaningful marginal analysis using the economist's definition could be developed to assist the manager in this profitable management of his business.

II. THE TRADITIONAL ACCOUNTING APPROACH VERSUS THE ECONOMIC APPROACH

General

Accountants have been entrusted with the recording of business results in the most pragmatic and efficient manner available.

Over the years they have developed techniques to record cash inflows and outflows and to compare these flows to other historical patterns. Accountants have been traditionally concerned with costs estimates in the following order of importance; financial reporting and planning, managerial control and finally decision making. In comparison, the economists have been largely confined to the educational and governmental institutions and have been concerned with the economic theories of price, demand and supply, and money.

In the business world today, the need for processed, analyzed, timely information is the source of much frustration. This impediment is in part a direct result of the gap between the pragmatic accountants and the theoretical economists.

Profit

One obvious rift is their conflict over the concept of profit. The accountants have tended to use the concept of net profit which is the
difference between outlay costs and net revenue. To the economists, true profit must include implicit and explicit costs and revenues. As accountants usually cannot define the explicit costs and revenues precisely, they are often ignored in an analysis. For decision making only costs and revenues affected by the decision should be included in the analysis. This includes both explicit and implicit costs. Consequently fixed costs were rarely included in a short range decision making process and the profit criterion for selecting strategies and programs were contribution to profit or marginal profit. The process of decision making is often relegated to the selection of the most profitable alternative. Often the alternatives could be adequately compared without determining the full extent of the profit, providing the decision maker was satisfied that the same fixed profits accrued to all alternatives under consideration. Thus, the selection of the most profitable alternative could be made by comparing variable profits, marginal profits and/or contribution to profit only. This concept has been developed more fully in the model. Generally the profit gain is only an estimate, because frequently there is a problem of associating the appropriate costs with the benefits or revenues accrued. Although the economists

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3 Fixed costs were used in this sense not only as defined by the accountants but also as costs which were not affected by a particular decision. In this sense costs which are a function of output could be classified as fixed, if the alternatives being considered did not affect those costs nor the output. As the short run is defined as a time span during which capacity does not change and the output is often constant, it could be stated that fixed costs would rarely be included in short range decision making as the decisions being made rarely affect them.

4 Hill, Thomas M. and Gordon, Myron J., Accounting a Managerial Approach Revised Edition; R. D. Irwin Inc. 1959 p. 324 "...fixed cost...may be defined as one which is independent of the level of output".
approach is conceptually the correct one but pragmatically a difficult one, a model can be designed to overcome many of the obstacles. Wherever possible costs have always been associated with the accrued benefits in the determination of profitability.

Costs

For most marketing decisions, cost information must be collected, collated, assembled, and classified on a specific basis and only those cost items affected by the decision should be included. The task at hand has been to establish those concepts and combine the accountant's viewpoints with the theories of cost, and focus both on the marketing decision.

Opportunity cost is the essential concept in all cost analysis for decision making. Costs may be an actual expenditure, or they may be the price that the product or service would command in the most productive alternative use. Utilizing the productive services of anything for one purpose is sacrificing the opportunity of using those services for other purposes. The true cost of these services then, is the value of the most productive foregone opportunity. The production cost of any product could then be defined as the value of the most productive foregone alternative product plus all further incurred processing costs.

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5 Howard, op. cit., p. 174.
6 Leftwich, op. cit., p. 136.
7 Value can be defined as a net worth of products or services to the economic system, in the real world selling prices are often a reasonable measure of net worth to the system. Value is measured in terms of price in the free enterprise economy and the valuation process is accomplished by consumers, themselves, as they spend their incomes. The dollar values which they place on each of the various goods depend upon how urgently
Opportunity cost is always the appropriate concept. Outlay costs, however, often measure opportunity costs, and can frequently be applied to the analysis. They are explicit costs and are measured by the traditional accounting approach. Implicit costs are an essential part of the economists' concept of cost. For example, there is an opportunity cost associated with self-owned self-employed resources. Since short run profit optimization is concerned only with costs affecting decisions in the short run, the opportunity costs of land, building, manpower, and other resources have been excluded.

7 - continued
consumers, as a group, desire each relative to other goods, their willingness and ability to back up desire with dollars, and the supplies of the goods available. For a true development of value, all foregone alternatives must have a proper total worth attached to them and the most productive alternative selected. This concept of value is developed more fully later in the thesis. Let it suffice to say that in this empirical example many components of the total value of each alternative are self cancelling when alternatives are compared to each other as only the additional or incremental value is of importance to the decision. Incremental value, or worth, for the purpose of this thesis can then be defined in terms of marginal profit.

8 There may be a problem with the development of relevant incremental cost data from accounting records which have been designed to provide average cost information. This problem could be overcome as evidenced further in the paper.

9 The short run is defined as the time period where the firm is unable to vary the quantities of some resources used, such as land, buildings, heavy machinery, and top management.
Revenues, whose measurement is plagued with conceptual difficulties, are in practice easier to determine. One definition of revenues which typifies the accountants approach is as follows; "Increases in owners' equity resulting from the operation of the business are called revenues,...". This is the accrual concept for measuring income, and it records events that change owners' equity in a specified time period. Another accounting concept is the realization principle which recognizes revenue not when goods or services are exchanged but at the moment an exchange agreement is reached. In essence revenue is created when the sale is made not when the goods are produced or delivered.

The economists, on the other hand, are concerned with the value of the flow of goods and services from producer to consumer. To measure value, the economist often uses the concept of value added. In economics the manufacturing process is regarded as creating value by producing products that can be sold and hence resulting in revenues. If inventories and prices remain relatively constant, production equals sales and the revenues created by manufacturing can be considered to approximate the accountants accrual concept definition of revenue. In this empirical example, the economists method closely approximates the accountants approach and for the purposes of this paper has been considered the same.

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10 Hill and Gordon, op. cit., p. 324.
III. MARGINAL ANALYSIS - RATIONALE AND ASSUMPTIONS

It has been verified\(^\text{11}\) that the maximum profit is earned when the marginal cost equals the marginal revenue for the volume produced and sold. Accepting this theory, \(^\text{12}\) suitable measurement devices to determine input and for reading the output must be found. The marginal analysis model became one of the bases for a profit optimization model.

Marginal revenue is defined as the change in total revenue resulting from a one unit change in sales. \(^\text{13}\) For the purposes of this model, it was desirable to simplify the concept of revenue and to use the concept of net revenue. Net revenue was defined as the selling price less the variable costs of distribution allowances, commissions and containers but not sales force costs, advertising or other marketing costs as these are defined as fixed costs in the short run. The implication of this definition is to define all markets, regardless of their proximity to the plant, on an equal basis for ease of comparison. The full impact of this reasoning will become self evident at a later stage.

Although in this empirical example the firm will not be operating under pure competition conditions, it will be shown that it is realistic to calculate the marginal revenue of a market segment under terms of pure competition. That is, the total market in some cases can be defined as a


\(^{13}\) Leftwich, \textit{op. cit.}, pp. 175-177.
finite number of blocks of business, where each block or segment in practice approaches conditions of pure competition within certain constraints. If this is the case, the selling price in each block (or in our case the net revenue per unit) equals the marginal revenue.

Marginal cost is defined as the change in total cost resulting from a one unit change in output. Another but similar definition is that marginal cost is the value of additional factors used to produce the marginal unit. However, the definition that is conceptually correct in the short run and that best suits the needs of business men trying to maximize their profits in the short run is that marginal cost is the increment in variable cost to produce a small number of additional units. Optimizing decisions in the short run focuses decision makers attention on the fixed versus variable cost distinction. As marginal costs are dependent on changes in total costs, fixed costs can be disregarded in the profit optimization model.

"Opportunity cost is a central concept in all cost analysis for decision making." "To use the productive services of anything for one purpose is to sacrifice the opportunity of using those services for other purposes. The cost of these services, then, is the most productive foregone opportunity." "The opportunity-outlay cost distinction is of

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16 Ibid., op. 179 and p. 183.
17 Ibid., op. 180.
18 Howard, op. cit., p. 173.
19 Ibid.
great practical importance, although its application is complex." One prime purpose of this chapter is to suggest how marginal costs for a marginal analysis can be calculated under particular conditions using opportunity costs. The accountant's concept of outlay costs in some instances may be a measure of opportunity cost as may his concept of replacement cost. The development of appropriate marginal costs from average variable costs using the opportunity cost concept will be developed in detail later.

Variable costs in the proposed model can be grouped into three classifications, marketing, plant processing and raw materials.

The majority of the marketing costs such as sales promotion, sales staff and other marketing and administrative expenses although variable in nature are usually fixed in practice with relatively little variation over small changes in output. For the purpose of this model these costs will be defined as fixed although this is not a necessity. The variable marketing costs involving distribution costs, allowances, commissions, and container costs will be deducted from gross revenue per unit to determine net revenue. This has no effect on the optimization model except to place all products for all customers in all containers on exactly the same base, (i.e. bulk product F.O.B. plant tanks).

\[20\text{ Ibid.}\]
\[21\text{ All sales inducing costs can be considered fixed as the selling effort to secure sales is usually constant in the short run. Although some marketing costs associated with the sale are fixed (i.e., administration) the majority of sales resulting costs are variable.}\]
\[22\text{ This approach does ignore the fact that different marketing efforts are expended to sell different customers, in different packages and as such, will affect the profitability and the marketing effectiveness. In this empirical example, it was not deemed important enough to justify the effort}\]
As many variable sales resulting expenses involve resources that are readily available from several sources such as the labour-sales pool, common carriers, container suppliers, etcetera, it can be assumed that the company's use of these facilities and resources will have no further effect on prices in the short run; such that the outlay costs can be assumed to approximate the opportunity costs.

The accounting function, if operating on a standard variable cost basis has already taken great pains to establish costs as variable, semi-variable, and fixed. Without further analysis, these distinctions may be used to develop average variable plant processing costs for the model. Depending on the business, many plant processing costs consist of commodity items, such as miscellaneous suppliers, heat, light, power, steam, water, labour and others which in most cases, the business in question rarely consumes a quantity large enough to affect pricing to an extent that outlay costs do not closely approximate opportunity costs. Consequently, these average outlay costs which approximate the true opportunity costs can be used as a measure of marginal costs of plant processing costs. Should the size of the purchases markedly affect prices, these items should be handled in a manner similar to that described in the next paragraph for raw materials.

In the opinion of the author, prices of the major raw materials in large corporations do not reflect opportunity costs, particularly if any of the materials come from self-owned resources or facilities. If

continued -
of categorizing marketing efforts by customer, by product. If it were desirable to do so, all marketing costs would become variable and would be apportioned accordingly. The author feels that this would not affect the conceptual solution.
this can be shown to be the case, another method must be developed to provide the opportunity costs for marginal analysis. Perhaps this disparity between outlay costs and opportunity costs can best be represented by a fruit cannery which owns its own orchards. Costs for the fruit consists of land, taxes, fertilizer, insecticides etcetera, and "picker's" fees. These outlay costs will represent an entirely different figures than the opportunity costs. The accountants would suggest replacement cost as the realistic figure to represent opportunity cost. The economist, however, suggest that the opportunity cost of the fruit is the value of foregone alternative products which resources used in its production could have produced. This opens up a whole host of alternatives, vegetable farming, industrial sites, housing developments and others, but in the short run these alternatives are not practical. Therefore it would appear that the opportunity cost of this fruit does not necessarily involve these other alternatives as they do not affect short run decisions. It is suggested that in the short run the opportunity cost is the value for which the products produced at that moment of time could draw in an alternative market place, or end-use. If this is the situation, it may be the price paid by another cannery or the price of the goods in the supermarkets. If a firm is engaged in a type of business where these alternatives are readily available such that it is able to sell either on the open market or to its own cannery, then it becomes a relatively easy task to establish opportunity costs of the raw materials for the cannery. If the grower could sell fruit on the open market for a

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23 This is the situation where either raw material prices due to some peculiarity do not truly represent the opportunity costs or where profit centers do not provide an adequate indication of opportunity costs. These situations will become more readily apparent in chapter three when the empirical example is discussed.
higher price than the cannery, it would do so; conversely if the cannery could purchase at a price below that of the grower it would also do so. This arrangement would continue until the price obtained by the grower equaled that paid by the cannery, at which time it would make no difference as to where the fruit was purchased. If the grower was forced to sell to the cannery at lower than market price, this would be a non-optimum solution and the total company would operate with less profit. The transfer price in this non-optimum solution would be the higher market value, quickly pointing out that the cannery is the non-optimum portion of the company.

To summarize, if outlay costs for the major raw materials are not the appropriate costs for optimal analysis, the alternate value concept may provide an adequate technique for the determination of these costs. If any firm produces products sold on the open market which also are used as raw materials for further processing, the appropriate raw material cost for optimal analysis is the lowest attainable net return or highest unaccepted price on the open market. Opportunity cost now takes on an added dimension of being the maximum value which could have been created by the best alternative use of the marginal unit of output. That is the highest unaccepted price offer for the marginal unit of output. \(^{24}\) A corollary is that both reproduceable and non-reproduceable products have an opportunity cost.

Using these concepts, it will be possible to develop a model in

\(^{24}\) Beckwith, *op. cit.*, p. 183.
which the optimum analysis will decide the proportion and transfer prices of the products used as raw materials for further processing. This analysis is of course directly influenced by the net returns obtainable for the up-graded products and the price of raw materials able to be borne by the up-graded products.

At this point, it is necessary to cement the relationships between variable costs, average variable costs, opportunity costs, and marginal costs which are used in the marginal analysis. The optimization model under development applies only to the short run and as it turns out only over relatively small changes in output. However, J. Johnston in his earlier studies states, "In general, average direct costs per unit of product will be expected to remain constant over large ranges of output, so long as the business continues to employ the same methods of production, and that the total of such costs will vary proportionately with total output". These relationships were found to hold in the empirical example used for this paper such that it lent itself to linear programming analysis. However, should average direct costs per unit not remain constant, a step function could be used which held costs constant only over limited ranges in output. This would make the model discontinuous at those outputs where costs changed. Joel Dean similarly commented and concluded that "...the most reliable estimate of marginal cost which can be made... is that it is constant... regardless of the rate of output." These relationships in this paper's model apply only to the manufacturing


\[\text{Joel Dean, Studies in Business Administration, Vol. 7, No. 1, 1936, "Statistical Determination of Costs with Special Reference to Marginal Costs".}\]
costs where the relationships hold true. This is not the case for all costs, particularly raw materials and Howard offers this cautionary note. "Limited empirical evidence suggests that average variable cost may sometimes be roughly equal to marginal cost of cost theory within narrow ranges of the level of output. The evidence is strong enough to suggest the use of average variable cost as a workable approximation of marginal cost over the usual range of production in some situations, but by no means all situations." In some cases the concept of incremental costs for additional units rather than marginal cost per unit is more readily determined. Howard again cautions and suggests that the incremental cost concept be used with care as some decisions involving this incremental increase involve long term commitments, consequently some costs ordinarily defined as fixed become incremental. Beckwith, however, rationalized that average variable costs were identical to incremental costs and could be used as a good approximation of marginal costs.

Another problem area could be the distinction between traceable and common costs as seen in the empirical example where caustic, chlorine, salt and hydrogen were all products of the same electrolytic cell. The difficulty was to meaningfully allocate the common variable costs to each product, and establish an acceptable basis for splitting costs among products. In this case, salt and hydrogen were discarded by-products and caustic and chlorine split the production costs on a molecular basis. This

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27 For further substantiation and a summary of the empirical evidence see J. Johnson, Cost-output Variations in a Multiple Product Firm, the Manchester School of Economics and Social Studies XXI (1953).
29 Howard, op. cit., pp. 177 - 178.
30 Ibid.
was justifiable because all excess products, \(^{32}\) that is, products produced but not sold, have an opportunity cost of zero. \(^{33}\) Since hydrogen and salt were excess by-products, it was decided that caustic and chlorine should bear 100% of the costs. Caustic and chlorine split both the processing and the raw material costs on a molecular basis as all costs incurred were for the prime purpose of splitting the salt molecule. \(^{34}\)

Howard \(^{35}\) suggests that the distinction between future and historical costs is important but often ignored. In practice historical costs were used even to make decisions involving future costs. The only solution applicable to this model was one of awareness, and to design the model with the flexibility to incorporate cost estimates of future conditions.

Economic theory sets forth two time periods; the short run applicable when the scale of output (plant capacity) is constant, but the rate of output can be changed, and the long run which applies when the scale and rate can be changed. Although the model being developed could guide long run decision making, many of the cost structures and relationships were not applicable to optimizing long run decisions. Consequently,

\(^{32}\) The concept of excess products having an opportunity cost of zero is discussed in greater detail later.

\(^{33}\) Although one plausible concept is for proceeds from the sale of by-products to be used to reduce production costs, it is only a question of associating costs with benefits. If by-products cannot be sold, then the products which are sold must bear the production costs. If one unit of these by-products is sold the revenue is usually classified as a contribution to corporate profit rather than a cost reduction.

\(^{34}\) This arbitrary split was made for convenience of operation in the model but is not conceptually required because if the costs are truly joint costs, any basis of cost allocation is arbitrary and of limited value in short run decisions. In the short run, one product would be considered a main product and the other a by-product. The split was also irrelevant, as market prices and the ability to sell the products determine the opportunity costs. The basic decision to either sell salt or to convert it into caustic, chlorine, and hydrogen is made in total as the decision to make any one product automatically makes the decision to produce the others in fixed proportions.

\(^{35}\) Howard, op. cit.
the model will be used primarily for short run profit optimization where the capacity is fixed.

Although no operations research tools such as correlation analysis and curve fitting techniques were used in this study to develop cost relationships, this does not preclude their use in other studies.

The measure for determining optimum conditions is contribution to fixed costs and profit where the contribution is the difference between net revenues and opportunity costs. When based upon opportunity costs this number is disregarded in financial reporting, for it bears little resemblance to outlay costs, the foundation of most financial statements. Double checking the optimum conditions described by the model verifies the optimum conditions in traditional financial terms.

IV. FRAMEWORK OF THE MODEL

A set of principles for establishing the profit optimizing model must now be developed. Theory of marginal cost output control differs from the optimum investment theory in fixed capital and may be practiced with or without optimum investment. 36 "It is worth repeating at this point that the practical application of any price-output theory to specific cases can only be guided by partial optimum analysis. The theory of a general optimum is useless for practical purposes, regardless of how mathematically elegant it may be, because it does not tell us how individual prices and outputs should be determined." 37

37 Ibid.
In the model the company's price-sales relationships for each product have been defined as a step function, with each step operating under terms of pure competition and representing the major business or market segment. Cost data and relationships have been built into a production matrix that has then been integrated into a marketing matrix. Physical quantities of production and sales were assumed to be equal so finished goods inventory remained constant. The model has then been programmed, using linear programs to seek the optimum conditions, occurring where marginal costs equal net marginal revenues. The model was designed to supply markets on raw materials in descending order of profitability until MR ≥ MC. The solution then became a straightforward linear program operating under the various constraints of capacity, markets, price and product.

The necessary input data consisted of process yields, production relationships, capacities, plant processing costs, raw material constraints and prices, market relationships including resale and exchange arrangements, market opportunities and alternatives, and net returns for each product by market segment. All input data was completely flexible and substitutable at any time to reflect new operating conditions or to study the effects of new alternatives or markets on profit and product allocations.

The basic solution furnished the following information within the established constraints; the optimum allocation of products to markets, and production facilities to supply these products; gross margin based on opportunity costs and if programmed, on outlay costs; and the marginal value
of resources, market opportunities and plant capacities. Essentially this was the change in profit resulting from an incremental increase in the employment of a resource, market opportunity, or capacity. These marginal values corresponded closely to the concept of value of marginal product for a particular resource.

The analysis provided opportunity costs for markets as well as products by establishing a product's value in alternative markets or processes. This was desirable as opportunity costs vary with the allocation of product to markets or processes. For products, then, opportunity cost could also be defined as the marginal value of the raw materials plus all processing costs - which include all production costs and the profit gained from a one unit change in market opportunity or plant capacity. If the products were restricted by production capacity, the opportunity cost would therefore equal the net return of the unsatisfied market. Without a capacity constraint, the program would supply the market until \( MR^2 - MC \) unless it became more profitable to upgrade this resource until another constraint was reached.

When excess products were not marketed nor upgraded, their marginal value would probably become negative and the opportunity cost would be zero. The opportunity cost of zero could be quickly checked by identifying the additional profit of selling surplus goods at below outlay costs. The opportunity cost of by-products normally would be zero and their sale ordinarily resulted in a contribution. Generally, excess products are by-products for most companies endeavour to produce only saleable products.

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38 Leftwich, op. cit., pp. 284, for further discussions.
39 The opportunity costs excluded a return on the investments facilities and other assets since these costs did not affect short run decisions.
Markets also have an opportunity cost equal to the net return in the market place less the marginal value for the market. The size of the market's opportunity cost is an indication of the profit importance, and the likelihood of a market being supplied should its size increase.

In many marketing situations it is expedient to produce and sell some markets which appear economically unsound. The reasons may be political or simply a volume consumer purchasing on an 100% requirements contract with a special price. Unless otherwise instructed the computer would preferably supply higher net business first and ignore the volume contract. As these relationships are forced, the program has been devised to provide the costs of forcing a non-optimum solution, defined as lost profitability in operating a non-optimum solution. The next chapter will also highlight some additional output which is of interest but not applicable to the concepts.

Economic theory suggests that all alternatives should be evaluated in a marginal cost-output analysis, however, in the short run where capacities and alternatives are limited, the number of variable alternatives are reduced to a finite number. Careful definitions and selection of empirical examples can overcome the many theoretical and practical objections to marginal analysis and provide a meaningful and useful analysis. Although some objections may have been neglected in the empirical example, none were serious enough to affect the correlation of the marginal analysis results with a financial analysis check.

Marginal value is zero or negative because usually excess products are a nuisance and incur a cost to dispose of them. Marginal value for a market is a concept advanced to measure the marginal contribution to profit of discarding the least profitable market in favour of another. The opportunity cost of the new market is equal to the market with the lowest net revenue being displaced. This concept is not an integral part of the thesis and is mentioned for interest.
V. THE HYPOTHESIS

Although there have been many approaches made to marginal analysis, there are few that have developed a rationale for using common place accounting principles in a marginal analysis. To the best of the author's awareness little specific work has been done on developing marginal costs for raw materials with alternative market values. Accordingly, it was hypothesized that economic and accounting concepts could be successfully melded under particular circumstances to exploit advantages of the opportunity cost doctrine when attempting to use a marginal analysis for optimizing profits in the short run. These particular circumstances involved a multiproduct firm manufacturing products which uses as raw materials, products the firm is already manufacturing and selling from an earlier processing stage.
CHAPTER III

THE EMPIRICAL SETTING

I. INTRODUCTION

Although a true empirical approach relies upon practical experience without reference to scientific principles, an empirical example was chosen which could develop the basic concepts in order to prove or disprove the hypothesis. An empirical environment was also required for a pragmatic application of these theories.

A chloralkali chemical plant empirical setting was chosen for its simplicity to highlight the concepts more explicitly. As the concepts of opportunity costing and marginal analysis are simple in theory and deceptively complex in application, this empirical setting was able to circumvent the less important but conceptually complex areas of application. In previous studies these areas often represented the primary source of difficulties and have limited the development of a pragmatic marginal analysis.

II. SIGNIFICANCE OF THE EMPIRICAL FRAMEWORK

One of the most desirable characteristics of this empirical setting was its extensive product range, which was vertically integrated and developed from relatively few raw materials. The vertical integration provided a product hierarchy which assisted in handling the difficulties associated with the alternate value concept. The basis for the development of the marginal cost curve were meaningful opportunity cost values for
products and raw materials, and a well defined variable costing system which could be related to the volume of output. The product hierarchy also helped develop the cost curves for raw materials, and a sophisticated variable cost accounting system facilitated the development of marginal costs for the balance. The marginal analysis concept has had limited success in practical applications. Some of the short-comings were associated with demand curve definition and the derivation of marginal revenues. In this example the proximity of the plant and its distance from competitors to markets insulated it from the outside world, such that short range price changes were usually a direct result of a condition change in the local environment.

The approach of the thesis has not been to establish new theories on marginal analysis or opportunity costing, but only to develop a pragmatic approach to the application of these theories. In addition a primary objective was to demonstrate how traditional accounting statistics can supply much of the data required for a marginal analysis. The development of a rationale for melding accounting techniques and economic concepts into a meaningful analysis was believed to be a prerequisite for the success of the analysis.

Information was freely available, and management co-operative in developing accurate statistics and meaningful relationships. The model was relatively simple and was based on linear production relationships. Its simplicity not only afforded the greatest propensity to establish a workable model but also offered a convenient apparatus for testing other theories.
III. DESCRIPTION OF THE EMPIRICAL SETTING

Background

From the electrolysis of common table salt, the chloralkali plant produced chlorine, muriatic acid, caustic soda, and calcium chloride. Chloralkali chemicals are heavy, low cost products, and are usually consumed in large tonnages. As transportation costs are a major factor, plants are located close to markets and raw materials. This plant is stationed in Western Canada on top of the great salt beds of Alberta. It is a small plant by industry standards built primarily to service one large petrochemical complex and a bleached kraft paper mill. As a result of limited demand and being the only chloralkali plant in the vicinity, it was necessary to expand vertically into chemistry which consumed caustic and chlorine as raw materials. Vertical integration was a defensive manoeuvre to consume chlorine as for every pound of caustic, approximately one pound of chlorine is produced. Upgrading chlorine into muriatic acid is preferrable to venting surplus chlorine into the atmosphere. These upgraded products also increase the plant's flexibility in maintaining the product balance as well as contributing to profits.

Description

This chloralkali plant produces less than one hundred tons per year of liquid chlorine. The chemical unit consumes salt, water, and natural gas, and produces bulk chlorine, chlorine cylinders, chlorine tonners, 50% caustic, 73% caustic, 50% purified caustic, 73% purified caustic, fused caustic, flake
Figure I
Chloralkali Plant Material Balance

Production Process
caustic, muriatic acid, calcium chloride, salt, and salt-calcium chloride mixtures.

The process begins with water being piped down to dissolve salt beds. The resultant brine is then pumped to the surface and impurities removed. (see Figure I). Treated brine is pumped to electrolytic cells and decomposed by direct electric current. Electricity is produced at the plant from natural gas. There are three products produced in the cell; hydrogen, gaseous chlorine and 10% caustic soda. In the caustic soda circuit the 10% solution is evaporated by steam heat to obtain a 50% solution. This solution is either shipped in tankcars or tanktrucks to customers, or additionally processed by further evaporation to 73% or purified to remove salt and chlorates. The 50% purified caustic can be sold directly or concentrated to 73% strength. A portion of the 73% caustic is concentrated to 100% and then drummed as a fused product or processed into flake caustic. Flake caustic can be shipped in drums or bags. The salt from the concentration and purification process is recovered in a centrifuge and dissolved as brine feed for the cells or used as saleable salt.

In the chlorine circuit, gaseous chlorine is cooled and dried with sulphuric acid and then compressed and liquified by refrigeration. Liquid chlorine is then loaded into tankcars, tonners, or cylinders for sale to customers. The portion of chlorine that cannot be liquified is used to manufacture muriatic acid by burning it with hydrogen, cooling the gas and dissolving it in water to produce the 31-35% strength hydrochloric acid known as muriatic acid. Acid is sold or used in manufacturing calcium.
chloride. Reacting lime rock and muriatic acid produces a 30% calcium chloride solution which is sold or upgraded into solid calcium chloride. This vertical product integration, and inter-relation of products in the product hierarchy is important in establishing opportunity costs and alternate values in the model.

Raw Materials

The material balance in Figure I illustrated that the raw materials purchased by the company have an opportunity cost which is different than the purchased cost of the raw materials. Raw materials owned or self supplied, such as gas and salt can be procured at a definable purchase price or sold at comparable prices for the quantities. For example gas is burned to produce steam and electricity, but limited generating capacity has necessitated the purchase of electricity from the utility company. However when the plant is shut down this capacity can supply the utility company. Consequently, several alternatives can be specifically defined, and opportunity costs and alternate values can be ascertained for self-owned, captive raw materials. Other supplies used in the process are consumable materials purchased on the open market from the best source of supply. Opportunity costs for these items were determined as discussed in chapter III.

Since caustic and chlorine are produced in fixed proportions, product frequently is purchased from or sold to other suppliers in order to maintain the output balance with demand.

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1 see Section III in chapter II.
Process supplies and maintenance materials are bought on the open market and their costs recorded as true outlay costs in the traditional accounting manner. In most cases purchases are so small that the market is not affected in any significant way. Hence an assumption was drawn that these materials and supplies were purchased under conditions approaching those of pure competition. As such, opportunity costs and alternate values are determined by outlay costs.

Markets

Most chloralkali chemicals are sold F.O.B. the seller's plant, freight equalized on the nearest competitive point, which is usually a competitor's plant. Consequently, the marketing effort and distribution costs are fixed costs to the company. Some products are sold on a delivered basis and others through agents or distributors. As the various distribution methods and the packages do not have fixed distribution costs, revenues were comparable only if the concept of net revenue was used. Net revenue was defined as the cash flow into the company after all freight, package costs, allowances, discounts, etcetra, were deducted. This figure was then free of all variable marketing and distribution costs and the alternatives open to the company were comparable on an equal basis. This common basis was defined as bulk product in the process storage tanks on plant-site.

Apart from occasional volume discounts, pricing in the industry was well defined, and rarely followed a short term demand and supply relationship. A customer's proximity to a plant and economical modes of transportation tend to affect the market price to a much greater extent. The major portion
of production is sold in bulk, in tankcars or tanktrucks to a relatively few customers. This pricing situation and size of individual shipments has segmented the market into a few well defined compartments. If a demand curve for each segment were drawn it would exhibit the shape of a stepped function with each step being smaller than the size of the tankcar or tank-truck. In the long run, transportation influences the expansion of new markets.

The markets available to the chloralkali operation consists of one large, bleached, kraft mill, one large petrochemical company, approximately twenty-five miscellaneous bulk customers, and many small customers who purchase products in smaller packages primarily through two distributors. Most bulk accounts are situated in Alberta and all package accounts are located within a 250 mile radius. This limited market has facilitated specific definitions of its size and opportunities.

Competitive plants are located in Eastern Canada, Manitoba, Saskatchewan and British Columbia. The marketing radius of these operations has been limited by distribution economics and as such do not represent active competition. The exception occurs where the marketing reaches of other plants overlap and then business is secured or lost on factors other than price.

More recently another chloralkali plant has been built in Alberta and it will directly compete with this one. It would be of interest to link this competitive factor into the marginal analysis model to test and develop new marketing strategies in a more dynamic model.
IV. CONCLUSION

Long range supply and demand relationships have not entered into the analysis because the objective has been to optimize the short run contribution of this particular firm and its own environment. The chloralkali empirical example has provided the necessary prerequisite to illustrate a pragmatic approach to marginal analysis. Although this situation has circumvented several difficulties, it has provided the framework for the development of a concept for profit optimizing in other situations. The next chapter has applied the basic concepts and integrated them into the empirical example for analysis.
FITTING THE CONCEPTUAL FRAMEWORK TO THE FIRM

I. INTRODUCTION

Consistent with the basic concepts presented earlier, this chapter has analyzed the firm's environment and markets as well as the general characteristics of the model itself. After objectives had been reviewed and input data calculated, the model's structure and operation were examined. The output and collective results have been presented and the discrepancies or deviations highlighted. This chapter has outlined the differences and similarities between the model and the basic concepts.

II. ENVIRONMENT

As discussed earlier, the markets of the chloralkali plant do not represent a linear demand curve, but constitute instead blocks of business which represent relatively fixed quantities at a given price for each block. In part, this results from low cost items being sold to major consumers such as the pulp and paper industry, the agricultural industry and the chemical industry. For instance, one or two bleached kraft mills usually consume the majority of the output of any one particular chloralkali plant. In the empirical example, the largest customer, a bleached kraft mill, was secured on an annual contract basis. Of the remaining business, approximately eighty percent is sold to eight other customers. Although other new business does exist, the opportunity is represented by one or two firms currently being supplied by the competitors, and by new firms
not yet in production. These market opportunities could be secured at the expense of the competitors. As the price of each market opportunity is well defined and generally supported by all competitors, business could be switched from one supplier to another by concentrating on non-price competitive factors like technical service, delivery, terms, availability of products, etcetera. This is not to imply that price was never an important competitive factor.

Competition stemmed from five other chloralkali plants within the marketing reach. These plants created competitive price levels but were far enough removed to diminish the daily competitive threat. There was often an element of cooperation between chlorlakali producers who traded or purchased product to maintain their production balance.

Price competition was generally held to a minimum with most products sold at the published list price. Pricing, however, does tend to be rather geographical in nature, and new price levels were customarily established by one of the large producer's acting as price leader. Other suppliers either followed or the price change withdrawn as a disproportionate amount of business would be placed with the most competitive supplier. Other price zones commonly followed a price lead which maintained the price differential caused by geographic or other factors. Price levels in the chloralkali industry were influenced as much by manufacturing costs as by market conditions. This information on prices and factors influencing price tended to prevent opportunistic pricing and lend a degree of pricing stability. Price stability has important implications on the marginal
analysis because only production rates were changed to achieve optimum conditions. Growth in the chloralkali business is steady with little seasonal variation.

The majority of the chloralkali products are sold in tankcar quantities which represent 100 - 200,000 lbs. of product per shipment. This package in itself creates blocks of business such that the demand curve for the chloralkali plant could be described as a step demand. In this empirical example approximately 500 shipments per year supplied all customers. Since the volume of this business was to two or three major customers, the remaining purchasers were easily defined in finite steps, each step being a multiple of the basic size shipment.

III. MARKETS

The chloralkali industry in Western Canada could be defined in economic terms as an unorganized collusive oligopoly with independent action. Industry pricing could partially be explained by a kinked demand curve, whereas each company's price structure can be represented by the step demand curve. Each block of business could be represented as a price competition model where marginal revenue equals the price and not price minus price divided by elasticity. Consequently, the marginal revenue curve was easily determined. (See figure two).

The concept of net revenue was reintroduced to help simplify the model. Net revenue represented the cash flow into the company from the sale of its products. As net revenues did not include distributor costs,

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1 For example, 110,000 lbs. for chlorine and 140,000 lbs. for caustic soda were common size shipments in Western Canada.
Figure II

Markets
allowances, or discounts, all blocks of business, regardless of location or sales outlet were placed on an equal basis. Consequently marginal revenue would be the net marginal revenue curve and would be on the same basis for all blocks of business.

Markets available to this plant were well defined for the short run, namely one major pulp and paper mill, four bulk chlorine, three 73% caustic, and sixteen 50% caustic soda accounts representing 90% of the bulk business. As these were the major opportunities open to the plant, and as a 100% share of business at these accounts was available it was relatively easy to define the demand curve for the products. A similar exercise was done for all products to all customers.

Since the majority of chloralkali products are sold FOB seller's plant, freight equalized against the nearest competitive supply point, outlining the additional opportunities was facilitated.\(^2\) (See figure two).

Opportunity analysis also suggests that all avenues and opportunities be defined and evaluated. The application of this concept could be a formidable and unrealistic task but the significant alternatives affecting a decision can often be defined and evaluated more easily.

The deductions from gross revenue for the calculation of net revenue and net marginal revenue have previously been defined. However, if costs were not directly associated with a market opportunity, they were averaged over all opportunities. For example; tankcar rental charges were averaged over all shipments by tankcars, even though some customers traditionally

\(^2\) Using the concept of net revenue and net marginal revenue the opportunity was defined as the selling price less the normal deductions less any equalized freight. It is perhaps obvious, but the positive evaluation of an opportunity by the model did not automatically assure that the business would be sought as other competitive factors will influence the decision. It
detained tankcars longer than others. Marketing costs remained relatively constant as the size of the sales force did not change with volume and many other marketing costs were borne by the distributors. Sales promotion and advertising was limited with expenditures remaining fairly constant. Similarly, other miscellaneous marketing costs did not vary with output and could be considered as fixed. This analysis justified excluding marketing costs from the analysis of the empirical example.

Due to peculiarities of the market and company, non-optimum conditions were often supplied at the expense of an optimum operating condition. The cost of forcing this non-optimum solution could be determined and was defined as the loss in profit resulting from the deviation. Many examples of this conditions could be cited, but many were either peculiar to the situation or a loophole in the model.

IV. THE FIRM

Utilizing the aforementioned concepts, marginal cost input data has been developed for the model. They were divided into the marginal costs of variable process supplies and marginal costs of major raw materials attempting to successfully meld the accountant's concepts with economic theories. Costs defined by the accountants as fixed in the short run have been excluded from the analysis as they did not affect short run optimizing decisions.

Certain minor consumable supplies which vary with output must be included in the analysis as a component of the cost function. The task was to find a suitable measure for the opportunity costs of these items. For

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3 One loophole forced the model to supply 100% of the pulp and paper company's business whereas the optimum solution was to supply other smaller higher net return opportunities. Unfortunately the pulp and paper contact was for total requirements.
many of these items the accountant's concept of outlay costs were used because the company produced chloralkali products, not consumable goods. The small volume of these supplies, are probably purchased under conditions approaching pure competition and the plant's requirement does not affect the general market price.

Opportunity costs are not necessarily marginal costs, but are often represented as average variable costs. Prior documentation verified that under most conditions average variable costs closely approximate marginal costs for small changes in output. For process supplies and miscellaneous items the average variable costs approximate their true marginal costs. In fact, it appears that due to the nature of the purchases and the quantities involved, the assumption appears valid over large variations in output.

A requirement of this analysis was that certain products manufactured for sale were also raw materials for other products and processes. This pre-requisite was necessary to establish the marginal costs of primary raw materials. Raw materials are variable costs which must be costed at the value of foregone alternative products with which the resources used in its production could have produced. It is reasonable to assume that resource allocation is well balanced to the extent that the resource pricing reflects the value of the foregone alternative products.

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4 This is a valid concept as a limited opportunity for these services in an alternative use exists and they represent a small portion of total costs. Consequently, the assumption has been made that service costs approximate the true opportunity costs and could be used to simplify the analysis.

5 See chapter two and J. Johnston, *op. cit.*

6 Process supplies and miscellaneous items include the variable components of almost all items other than major raw materials, such as maintenance materials, process reagents, catalysts, hourly paid labour, steam, light, power (other than cell current) and minor raw materials (electrodas, water treatment chemicals, etcetera).
Establishing marginal costs of raw materials was not easily accomplished for many products and raw materials were derived from self employed resources. The objective was to determine the marginal costs by defining the opportunity cost for raw materials as the value of products produced at a specified moment in an alternative market place or end-use. For example, chlorine is sold to five bulk customers and many 150 pound and tonner container customers and is also up-graded into HCL or muriatic acid. The chlorine raw material cost to the HCL unit would be equal to the net returns available in the next most profitable market or end-use. It is the value which other customers pay to secure the resource for another purpose. This alternative value or opportunity cost concept could be applied to each resource with the option of selling the product or of using it was a raw material for further processing. Consequently, the opportunity costs of the output are also the marginal costs of the resource, and the marginal costs for raw materials are readily definable. Marginal costs change with the allocation of product to alternate opportunities as opportunities are either secured or released in accordance with the model's optimum solution.

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7 This statement could be disputed on a theoretical basis, but there were no contrary indications in the empirical example. (See discussion on value in Chapter II p. 12.).

8 Using Figure I it could be seen that this method established opportunity costs for all raw materials except lime rock, hydrogen and raw brine. Brine, however, could be manufactured from saleable salt and this value used to determining the opportunity cost. In this example, raw brine could not be sold as such, so the opportunity cost was zero, and the cell brine had a value equal to the variable costs to treat raw brine. Hydrogen also had no alternative market and its opportunity cost was zero. Outlay costs were used for lime rock which was purchased in small quantities at prices equivalent to other users.

9 This assumes the relationship between average variable costs and marginal costs set forth in J. Johnston, *op. cit.* In several cases this relationship using the opportunity costs concept can be proven by inspection of the model.
V. MODEL STRUCTURE AND ANALYSIS

Another pre-requisite for this analysis required definable and obtainable variable costs for each stage of the production process. The truly variable cost components of supplies and process cost were established by the accountant's traditional standard variable costing technique. Each production process was defined using marginal costs in a mathematical relationship and each market opportunity defined in terms of marginal revenues and volume potentials in order to develop the profit equation to be optimized. All production and market constraints were defined and quantified before the function which used linear programming techniques was optimized. This was instituted by developing a product-resource allocation operating the plant as close to MR\_1\geq MC\_1 as possible.

Essentially the model is composed of two matrices; the production matrix containing process yields, relationships, capacities, costs and constraints, and the market matrix describing market opportunities in terms of net prices or returns, volume, relationships and constraints.

The model was verified by applying outlay costs and market prices to check the effect on profit margin of optimum solutions under different conditions. Thus optimum solutions were expressed as a profit and loss statement which was the essence of the exercise.

The output of the model although incidental to the thesis provided the following information:
a) the optimum allocation of products to markets and the optimum production facilities to supply these products.

b) the gross margin at this optimum allocation.

c) the marginal value of market opportunities and plant capacities. Marginal value was described as the increase in profit resulting from an increase in the market opportunity or plant capacity by one unit.

d) opportunity costs of a market or product opportunity. This gave the minimum profitable net return for a product to cover variable manufacturing costs including the marginal value of its raw materials.

e) the costs of forcing a non-optimum solution. These were the increased costs or reduced profit incurred by forcing a non-optimum market or production activity.

f) other items such as contributions to gross margin of individual products or markets, sensitivity of gross margin and optimum allocation to costs, net returns, and other input data. This was the point where the solution drastically changed with only small changes in input. Another item was the range over which incremental values and optimum solutions are valid. As the opportunity of a market changes, the marginal value of the market applies only as long as the basic solution does not change. The range over which this marginal value applies was found by right hand side ranging. It was also possible to determine the effect on total profits of several simultaneous changes; to develop profit centers and transfer prices, and many other bits of information which help decision making.

Most of the model's additional benefits focuses on data suitable for marketing decisions.
The net result of the analysis isolated the least profitable and most profitable markets suggesting where a marketing effort should concentrate. It also indicated markets and production units which had an abnormally large impact on profitability and pointed out the misconception of the dependance of the business on one large customer. The analysis instituted re-evaluation of the marketing strategy and an investigation into pricing policy.

VI. REVIEW OF THE HYPOTHESIS

In one particular chloralkali plant, accounting techniques and principles were selectively used to develop several economic theories into a pragmatic model for more effective decision making in the profitable management of the firm. Although some economic theories were loosely applied, and the empirical example did avoid specific conceptual and pragmatic difficulties, the analysis furnished an information base for making sounder decisions. The chloralkali plant was selected for its integrated product line and isolated markets. However, the author has applied the concept to other companies and believes it is valid for other industries. The procedure must be carefully applied in the more diversified areas because the alternate values become vastly more complex with wider product ranges, markets, and many producing points.

The hypothesis states that under particular conditions a combination of economic concepts and accounting principles could exploit advantages of the opportunity cost doctrine using a marginal analysis for
optimizing profits in the short run. These circumstances involve a multiproduct firm manufacturing products which use as raw materials, products the firm is manufacturing and selling from an earlier processing stage.

Within the limited context of the hypothesis, economic concepts and accounting principles were used to develop a profit optimization model using the opportunity cost doctrine in its entirety. The model although specific to the empirical example, provided information for optimization and successfully applied the concept for sound decision making. This statement partially represents a management value judgement for the analysis only highlighted non-optimum operating conditions. Also management was made aware of sensitive areas and conditions which could have resulted in unnecessary marketing tactics pursuing an erroneous marketing strategy. In concluding, the hypothesis has been accepted with reservations and the concept shown to be sufficiently workable to be applied to more complex situations.
CHAPTER V

CONCLUSIONS

I. INTRODUCTION

Conclusions are the last part of a chain of reasoning in a discourse and by definition a place where opinions formed during the investigation could also be presented. Accordingly, this chapter has presented a brief summary of findings before the conclusions are drawn.

This discourse has offered a practical approach to profit optimization using recognized theories of accounting and economics. This approach, however, is applicable to only certain situations which are partly circumstantial and partly due to management's philosophy and the corporate's objectives. Profit optimization in the short run was particularly conducive to vertical integrated multiproduct firms where short term profit maximization was a primary objective. This thesis has ignored other corporate objectives except in their relation to the short term profit objectives.

II. REITERATION OF MAJOR FINDINGS

The optimization technique, through selection of the empirical model, overcame many of the indigenous problems to marginal analysis. The successful application of this technique has shown that a business could be managed using alternate values which do not relate to outlay or accounting costs. Thus, major findings could be separated into pragmatic and conceptual findings.
Pragmatic findings concern the application of economic and accounting ideology to marginal analysis or profit optimization. Although idealistic in nature, marginal analysis and alternate values provided meaningful guidelines for the short run optimization of profits. Most input information was developed from traditional accounting technique concerned with financial control. Although these did not blend smoothly with the economic concepts, they did provide a portion of the required bank of information.

With the accountant's data base, economic idealism and marginal analysis concepts were formulated into a workable mechanism for profit optimization. Evolving unique marginal revenues and marginal costs overcame many of the difficulties associated with other studies. The two most significant breakthroughs were the concept of net marginal revenues for each block of business and the application of opportunity cost and alternate values to marginal analysis. The economic definitions of opportunity cost and alternate values applied in a localized short term environment simplified their definitions and determination. Thus opportunity costs and alternate values were available in many situations, but the ease of their determination depended largely on the empirical example. The establishment of marginal costs using opportunity cost and alternate value concepts as defined by the economists profit equation resulted in costs being ascertained and influenced more by the product demand relationships than by the costs recorded in the financial control system. If this observation were valid, it would be impossible to successfully meld accounting principles and concepts with economic theories in profit optimization models.
Some unexpected information and important ancillary data were furnished by the model and a greater comprehension of marginal costs, alternate values, and opportunity costs were attained. Values for special conditions were defined. For instance; at best, the opportunity cost of excess products are zero. The production cost of each product manufactured in one production step is directly proportional to the demand or alternate value of that product. The marginal value of resources, market opportunities, and capacities are examples of the ancillary data which could provide useful statistics for assessing the impact of decisions and providing guidelines for future action plans. An information base, preferable to the accountant's statistical records, was established for estimating the impact of new or non-optimum decisions on profit in the short run.

The conceptual and possibly ideological findings were a direct result of the attempt to meld accounting techniques with economic theory. It was suggested that costs associated with profit optimization are markedly different than those recorded by the accountants. For profit optimization models it would appear that only alternate values and opportunity costs with only outlay cost constraints should be used in the model. Opportunity costs and not recorded outlay costs are the appropriate concept for any profit optimization technique involving the marketing of the company's products.

It was observed that some product costs with fixed production relationships were dependent on demand relationships for the final product
rather than on raw material or process costs. If this finding was valid, a function relating product demand and production relationships to cost could be developed, differentiated and solved for least cost relationships.

III. CONCLUSIONS FROM MAJOR FINDINGS

For purposes of profit optimization it was undesirable to combine accounting techniques with economic theories, but some data contained in the record keeping system could be successfully applied if carefully selected. The application of alternate values and opportunity cost concepts to marginal analysis profit optimization did lead to a useful analysis in this empirical example, with the possibility of application to many other companies.

Criticism could be directed to administering the "Black Box" approach and ignoring the effect of changes in opportunities and actions on its environment, namely the industry or economy. If a major change in the company's modus operandi affects the environment, or vice versa, these relationships could then be studied independently of the internal segment of the "Black Box". The resultant change in the company's opportunities could then be re-analyzed for the optimum solution.

It is often stated that profit management and planning require different techniques and information than cost control and no accounting system should be used for profit management and planning. In some companies, these techniques closely approximate one another, but in the empirical example the

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1The "Black Box" technique isolates a complex portion of a system and analyzes the part measuring only inputs and outputs from the total system or vice versa. The total system could also be examined ignoring the section in the black box except for its inputs and outputs to the system.
accounting technique could only cost control and could not profit manage the company affairs. Although this profit optimization technique has been applied successfully and has lead to decisions increasing gross profitability like all operations research tools, it only provided information and suggested courses of action, and did not replace the decision maker.

Costs, as defined in the economic profit equation change with the opportunities available to the company, and therefore in a multiproduct company with inter-related product lines, variable costs were as meaningless as fixed costs for short run profit optimization. Outlay costs for individual raw materials affected the analysis only by constraining a total variable cost outlay on the company as an entity, beyond which it was more economical to close the plant. The extent of this conclusion will vary with each company according to available opportunities and the degree of product inter-relation. For companies with limited idealistic alternatives and product lines which are not inter-related, the traditional accounting approach to profit control and management would suffice.

The hypothesis stated that "Economic concepts and accounting principles can be successfully melded under particular circumstances to exploit advantages of the opportunity cost doctrine when attempting to optimize profits in the short run. These particular circumstances involve a multiproduct firm manufacturing products which used as raw materials, products the firm is already manufacturing and selling from an earlier processing stage." This hypothesis must be rejected because the basic premise of combining economic concepts and accounting principles was undesirable and
incorrect for profit optimization. Accounting principles guide management and planning through the analysis and control of historical cost information and alternatives. In some situations these interpretations satisfactorily measure opportunities and their costs to give acceptable results. On the other hand, the balance of the hypothesis could be unequivocably accepted since the opportunity cost doctrine was successfully exploited using the economic theory of marginal analysis to optimize profits under the conditions stated. The true measure of the success of this thesis was in the ancillary problems and solutions gained by this analytical approach.

IV. UNSOLVED RELATED PROBLEMS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The entire analytical procedure has ignored the impact on long range strategy. This is due to a different dimension of capital expenditures, changing capacity and the possibility of a different demand curve or product line, and further research should relate the effect of many models with various parameters simulating a long term effect.

In addition the company's environment, the industry and economy has largely been overlooked. It should be possible to expand this technique to the industry or world economic levels to achieve a similar short run optimization solution. The concept of the "Black Box" would be appropriate if applied in reverse.

Further scope for analysis of the other output from these models mentioned in Chapters two and four is available. This data, the model, and
other operations research techniques may well be the forerunner of a new
data base and simulation program for the profitable direction of a company
or industry. This type of information system is an urgent requirement for
business managers who like their predecessors still continue to conduct
their business by intuition.


Culliton, James W. The Management of Marketing Costs. Boston: Graduate School of Business Administration, Harvard University, 1948.


Johnston, J. "Cost Output Variations in a Multiple Product Firm", The Manchester School of Economic and Social Studies. XXI, 1953.


APPENDIX
APPENDIX

THE CHLORALKALI MODEL

In a capital intensive industry such as chloralkali where variable costs represent a small proportion of the selling price, the cost information as provided by a standard cost accounting system did not provide the required information for guiding the company decision makers. The best alternative at the time was to develop costs based upon alternate value or opportunity costs. Thus the cost of securing an alternative was equal to the net return of the best alternative. To give guidance in setting the production rates, production mix, and the best allocation of products to markets, the concept of marginal analysis was introduced to determine maximum profit conditions. Often the conditions for maximum profit could not be immediately implemented due to other factors which could not be included in the linear program model. For example, the impact of a change in the chloralkali divisions policy or marketing philosophy on the overall corporation was difficult to measure and many decisions were made within the constraints of overall corporate policy.

The linear program as developed for the corporation was relatively straightforward in construction but large in size with 144 variables in the program. Many of the variables were used to define relationships and conditions more precisely and
have little significance to the model itself. To illustrate the basic construction, a simplified model has been developed. Out of necessity the precise quantities and relationships have been changed to avoid the release of confidential information.

I. SIMPLIFIED MODEL

<table>
<thead>
<tr>
<th>CONSTRAINTS</th>
<th>R.H.S.</th>
<th>X₁</th>
<th>X₂</th>
<th>X₃</th>
<th>X₄</th>
<th>X₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROFIT $$/TON</td>
<td>-7.2</td>
<td>-0.3</td>
<td>-5.1</td>
<td>6.3</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>D.C. POWER CAPACITY = kWh</td>
<td>75.0</td>
<td>2.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELL CHLORINE POOL = mTon</td>
<td>0</td>
<td>-1.0</td>
<td>+1.03</td>
<td>1.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELL CAUSTIC POOL = mTon</td>
<td>0</td>
<td>-1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BULK CAUSTIC POOL = mTon</td>
<td>0</td>
<td>-1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% CAUSTIC POOL = mTon</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHLORINE OPPORTUNITES = mTon</td>
<td>28.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAUSTIC OPPORTUNITES = mTon</td>
<td>30.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Algebraic Representation

\[ +2.75 \times X₁ \leq 75.0 \]
\[ -1.0 \times X₁ + 1.03 \times X₂ \leq 0 \]
\[ -1.1 \times X₁ + 1.06 \times X₃ \leq 0 \]
\[ -1.0 \times X₂ + 1.0 \times X₄ \leq 0 \]
\[ -1.0 \times X₃ + 1.0 \times X₅ \leq 28.0 \]
\[ -1.0 \times X₄ \leq 30.0 \]

MAXIMIZE PROFIT = \(-7.2 \times X₁ - 0.3 \times X₂ - 5.1 \times X₃ + 63.0 \times X₄ + 60.0 \times X₅\)
**Imput Requirements**

a) Process yields and production relationships  
b) Plant capacities  
c) Variable operating costs  
d) Market constraints  
e) Market relationships  
f) Net returns for each product by market  

The values of the first three items changed infrequently and constituted the basic production matrix. These were only updated whenever plant changes occurred. The marketing items would change from time to time. The imput was completely flexible. Any of the market data, yields, capacities or costs could be revised or deleted and the new markets or facilities added to study their effect on profit and on optimum allocation of products and facilities.

**Output Information**

a) optimum allocation of products to market and optimum allocation of production facilities to supply these products.  
b) gross margin as determined by the accountants variable costing system.  
c) opportunity cost of a market opportunity or product.  
d) marginal value of market opportunities and plant capacities.  
e) cost of forcing.
The model could also be programmed to provide the following:

a) contribution to gross margin of individual products or markets (parallel studies or parametric programming)
b) sensitivity of gross margin and optimum allocation to costs, net returns and other input data. (cost ranging and sensitivity analysis)
c) range over which marginal costs are valid. (right hand side ranging)
d) effect on profit and allocation of a simultaneous change in several costs, net returns or market constraints.

II APPLICATION OF THE MODEL


In this small chloralkali plant there were over 100 major product-market relationships and each of the fifteen major products had different marketing reaches. As all products were derived from salt, the relationships were interrelated. Other than intuition there was little to guide management in determining the optimum allocation of products to markets. Without belabouring the point, nor being involved with precise relationships, it could be shown that the model suggested a different course of action than variable cost analysis.
eg: Chlorine can be sold or used to manufacture muriatic acid which in turn can be sold or reacted with limestone to produce calcium chloride.

\[
\text{Cl}_2 + \text{H}_2 \rightarrow 2\text{HCL} \\
\text{HCL} + \text{CaCO}_3 \rightarrow \text{CaCl}_2
\]

**Chlorine:** net return of last ton supplied $60, next ton of opportunity at $60

<table>
<thead>
<tr>
<th></th>
<th>marginal revenue</th>
<th>variable cost</th>
<th>contribution</th>
<th>marginal cost</th>
<th>m.r. - m.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>marginal revenue</strong></td>
<td>$60/ton</td>
<td>$8/ton</td>
<td>$52/ton</td>
<td>$60/ton</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Chlorine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>marginal revenue</strong></td>
<td>$31/ton</td>
<td>$5/ton</td>
<td>$26/ton</td>
<td>$31/ton</td>
<td>$0</td>
</tr>
<tr>
<td><strong>HCL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th></th>
<th>marginal revenue</th>
<th>variable cost</th>
<th>contribution</th>
<th>marginal costs</th>
<th>m.r. - m.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>marginal revenue</strong></td>
<td>$68/ton</td>
<td>$29/ton</td>
<td>$39/ton</td>
<td>$55/ton</td>
<td>$13/ton</td>
</tr>
<tr>
<td><strong>CaCl\textsubscript{2}</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**capacities per day:**
- chlorine 50 tons
- HCL 25 tons
- CaCl\textsubscript{2} 10 tons
Rank by

a) Contribution/ton  b) Contribution/day  c) M.R. - M.C./ton

2. CaCl₂ $39  2. HCL $ 975  2. HCL $ 0
3. HCL $26  3. CaCl₂ $260  3. Chlorine $ 0

Analysis by contribution suggested that the company concentrate on chlorine. Analysis by the model however suggested that the greatest profit improvement would come from concentrating on calcium chloride and that either prices of this product could be lowered to increase volume or the marketing reach extended until the marginal revenue equaled the marginal cost of $55/ton or until capacity limited. Should capacity limit sales an expansion should be evaluated using net returns between the last accepted and $55/ton. If lower prices for chlorine or muriatic acid are accepted, calcium chloride becomes all the more attractive.

Establishing production rate and Balancing Sales with Production:

One problem often encountered by managers of chloralkali plants was the decision to purchase product and reduce output, or to maintain output and seek new short term markets in order to maintain the chlorine/caustic sales/production balance.

For example: If 73% caustic were in short supply and could be sold at the lowest net return of $57/ton, what would be the correct decision if caustic could be purchased at $60/ton.
One solution was to produce sufficient caustic to meet this requirement. However as 1.0 lb. chlorine was produced for every 1.1 lb. of caustic, chlorine would be surplus. The dumping of surplus product in new markets on a sporadic basis was undesirable from a competitive standpoint as other chloralkali producers would retaliate and destroy the stability of the market.

The first observation is that caustic purchased at $60 and sold for $57 is unprofitable, however as a 100% contract is involved, the purchased material actually maintains supply to a $65 market and a profit is made on the resale.

(i.e: $57 - 60 + 65 - 60 = $2/ton)

There are of course other alternatives to operate at a production level where caustic production equals sales. Chlorine would then be upgraded into other products and higher inventory levels of chlorine based products would be maintained until sales and production were balanced. This meant the development of other markets for chlorine based products in an orderly fashion. Which markets, at what prices, with what products, then became the decision. Obviously the most profitable ones, and management must decide whether the pursue bulk chlorine, chlorine tonners, chlorine cylinders, muriatic acid, calcium chloride, lump, flake, granular, special fines or liquid markets and determine the acceptable net returns for each and the optimum allocation of product to market. (The optimum allocation could change with every new piece of business.) On the other hand
it may have been more profitable and easier to reduce sales of caustic
based products and selectively market these products. And there would
be an equal number of alternatives to the marketing of caustic and
cauastic based products.

Management's solution to this problem in the past was to take
the easiest course of action. There was initially a push in the sales
department to sell the surplus products. If this failed, after inventories
had increased, surplus product was offered to competitors. If a sale
couldn't be arranged, production was reduced to bring chlorine into
balance and the shortage was purchased. Careful planning and years
of management experience usually avoided a crisis and the company
continued to make a profit. Prices were established at a level the
market would bear and new capacities for any product evaluated on its
own merits.

Without using the model, the analysis was largely intuitive
as the costing system maintained by the company did not provide the
necessary guidance. The large number of alternatives to be considered
lend themselves to computer analysis and make manual analysis impractical.
Using the model, however, the effect of each change or anticipated change
could easily be assessed, the new optimum condition determined, and
positive action taken.
Other:

There are many applications for the model which ranged from assessing the profit impact of; changes in the market size and composition, price changes, loss of a major customer, a nonoptimum decisions, an inoperative production unit, a strike or act of god, and any proposed decisions. One other major application of the model was to evaluate several expansion alternatives and determine the correct sizing of each unit.