PROGRAMMED PROFIT ANALYSIS

FOR SAUSAGE MANUFACTURING

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TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF APPENDIX TABLES	vii
LIST OF ILLUSTRATIONS	ix
ABSTRACT	x
CHAPTER I. INTRODUCTION	1
Competitive Structure	2
Volume-Cost-Profit	3
Functional Decision Areas	4
Formulation	5
Ingredient Procurement	7
Product Line	8
Labor and Facilities	8
Interplanting	9
Sales Policy	10
Production Planning	10
CHAPTER II. METHODOLOGY AND MODEL STRUCTURE	12
Methodology	12
Use of Linear Programming	13
Necessary Mathematical Conditions	14
Structure of the Model	15
Economic Parameters	15
Mathematical Statement of the Model	18
Activities of the Firm	20
Ingredient Procurement	20
Ingredient Use	21
Formulation	21
Production	22
Distribution	22
Sales	22
Volume-Cost-Profit Summary	23
Cost and Revenue Summary	23
Constraints	24
Ingredient Supply	24
Ingredient Use	24
Formulation	25
Production	26
Distribution	26
Sales	26
Volume-Cost-Profit	27

	Page
Volume-Cost-Profit Analysis	28
Financial Analysis	32
Input Data Uncertainty	34
CHAPTER III. MODEL APPLICATION	36
Decision Guides	36
Procurement	38
Formulation	40
Production and Distribution	46
Sales	55
Operating Summary	64
Results of Parameter Changes	65
Production Capacity	65
Prices	69
Ingredients	69
Meat Cost	70
Computation	76
CHAPTER IV. SUMMARY AND CONCLUSIONS	78
Summary	78
Conclusions	81
Further Study	82
BIBLIOGRAPHY	84
APPENDIX A	86
APPENDIX B	91
APPENDIX C	117

LIST OF TABLES

Table		Page
1	Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week I	41
2	Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week I	44
3	Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week I	46
4	Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week I	47
5	Value Guide for Ingredients Not Used, Case Study Firm, 1963, Week I	49
6	Production and Distribution Guide, Case Study Firm, 1963, Week I	51
7	Company Labor Utilization Guide, Case Study Firm, 1963, Week I	52
8	Plant 1 Labor Utilization Guide, Case Study Firm, 1963, Week I	52
9	Plant 2 Labor Utilization Guide, Case Study Firm, 1963, Week I	52
10	Plant 3 Labor Utilization Guide, Case Study Firm, 1963, Week I	52
11	Labor Expansion Guide, Case Study Firm, 1963, Week I	53
12	Plant 1 Sales Guide by Market, Case Study Firm, 1963, Week I	57
13	Plant 2 Sales Guide by Market, Case Study Firm, 1963, Week I	58
14	Plant 3 Sales Guide by Market, Case Study Firm, 1963, Week I	59
15	Total Sales by Product, Case Study Firm, 1963, Week I	60

Table		Page
16	Sales Promotion Guide by Product, Case Study Firm, 1963, Week I	62
17	Estimated Operating Statement, Case Study Firm, 1963, Week I	66
18	Operating Statement Components for Alternative Labor Hiring with Week I Prices, Case Study Firm, 1963	68
19	Procurement and Utilization of Regular Pork Trimmings as Prices Change, Case Study Firm, 1963	68
20	Meat Cost Variation between Plants as Prices Change, Case Study Firm, 1963	71
21	Production Location as Prices Change, Case Study Firm, 1963	73
22	Variation in Labor Hiring as Prices Change, Case Study Firm, 1963	75
23	Variation in Operating Statement Components as Prices Change, Case Study Firm, 1963	75

LIST OF APPENDIX TABLES

Table		Page
	Appendix A	
1	Labor Hiring Ranges, Case Study Firm, 1963	88
2	Freight Rates Between Plants, Case Study Firm, 1963	88
3	Ingredient Prices for Model Test, Case Study Firm, 1963	89
4	Product Prices for Model Test, Case Study Firm, 1963	90
	Appendix B	
1	Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week Ia	91
2	Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week Ia	92
3	Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week Ia.	93
4	Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week Ia.	94
5	Production and Distribution Guide, Case Study Firm, 1963, Week Ia	96
6	Company Labor Utilization Guide, Case Study Firm, 1963, Week Ia.	96
7	Estimated Operating Statement, Case Study Firm, 1963, Week Ia.	97
8	Total Sales by Product, Case Study Firm, 1963, Week Ia .	98
9	Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week II	99

Table		Page
10	Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week II	100
11	Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week II	102
12	Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week II	103
13	Production and Distribution Guide, Case Study Firm, 1963, Week II	105
14	Company Labor Utilization Guide, Case Study Firm, 1963, Week II	105
15	Estimated Operating Statement, Case Study Firm, 1963, Week II	106
16	Total Sales by Product, Case Study Firm, 1963, Week II	107
17	Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week III	108
18	Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week III	109
19	Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week III	111
20	Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week III	112
21	Production and Distribution Guide, Case Study Firm, 1963, Week III	114
22	Company Labor Utilization Guide, Case Study Firm, 1963, Week III	115
23	Estimated Operating Statement, Case Study Firm, 1963, Week III	115
24	Total Sales by Product, Case Study Firm, 1963, Week III	116

Appendix C

1	Description of Flexible-Formula Product Formulation Matrix	118

LIST OF ILLUSTRATIONS

Figure		Page
1	Functional Decision Areas as Related to Contribution to Fixed Cost and Profit of Sausage Manufacturing Firms . .	6
2	Condensed Matrix of Sausage Manufacturing Model	19
3	Model Segment for Labor Hiring and Utilization	30
4	Model Segment for Financial Analysis	33
5	Flexible-Formula Product Formulation Matrix	117

ABSTRACT

Armbruster, Walter Joseph. M.S. Purdue University, June 1964. Programmed Profit Analysis for Sausage Manufacturing. Major Professor: Dr. James C. Snyder.

Differences in volume and margins among the various products point up the importance of volume-cost-profit analysis adapted to the particular sausage manufacturing firms. The relationships of the various cost and revenue factors to volume are of extreme importance in determining the profitability of the sausage manufacturer.

The individual functional decision areas are closely related to overall volume-cost analysis. For purposes of this study, the functional decision areas considered included: formulation problems, raw material procurement, product line policy, physical facility utilization, interplanting green materials and finished product, gang size for labor hiring, production planning, and the general area of sales policy, particularly distribution and pricing decisions.

A normative linear programming model was built to simultaneously consider all the decision areas and alternatives. The analysis was undertaken as a case study to permit incorporation of consistent data in the model. In addition, it permitted building the model around the type of management analysis necessary for it to be useful in an operational setting. The model tested for the case firm contained 727 variables representing activities of the

firm and these activities were controlled by 585 constraints. The model was designed as a weekly decision model representing a three-plant firm selling seven major sausage product lines in two major types of markets. The sausage division represented by the model could purchase up to 16 ingredients from job-lot, car-lot, or in-company sources.

The firm is generally a price taker in both the product and ingredient markets. Traceable variable costs were allocated to the appropriate products, whereas common variable costs are a function of total output. The model was designed to maximize short-run contribution to fixed costs and profit. Maximization of the long-run contribution is the actual objective of the firm and this is considered in setting constraints on the short-run decisions.

Four phases were analyzed for the case firm. The first phase analyzed involved production capacity as the limiting factor. In the second phase analyzed, market sales became the limiting factor, _ceteris paribus_. The third and fourth phases likewise were limited by market sales as the levels of ingredient and product prices changed.

The optimal solutions obtained from the different phases showed changes for the various decision areas. Ingredient procurement sources and quantities of each ingredient used at different plants changed as prices varied. Formulas for products with their associated meat costs varied among plants under a given set of conditions and between time periods at the same plant as conditions changed. Production location also changed under varying conditions even though total production volume remained constant. Closely related to these production shifts were changes in the optimal labor-hiring patterns.

Contribution to fixed costs and profit varied widely with changing market conditions. The amount by which estimated profit contribution exceeded the profit objective in the analyses indicated the general magnitude of profit improvement attributable to use of the model. These figures represented approximately 9 percent increases in contribution to profit above the profit objectives.

Use of the model adapted to the individual company's conditions may be expected to result in improved profits through reduction of suboptimality for the company.

CHAPTER I

INTRODUCTION

Sausage manufacturing firms have the same objectives as do firms in general, the chief of which is profit maximization. The relevant objective of a company is maximization of expected long-term contribution to profit.1/ Profit maximization is affected be secondary objectives of the firm and is further complicated for sausage manufacturers by large numbers of interrelated alternatives.2/ Even though other factors enter and complications are many, within the restrictions dictated by competition and society ". . . profits are the acid test of the individual firm's performance".3/

The purpose of this study was to develop a quantitative model to simultaneously analyze the many factors involved in making the optimal decisions for routine operations of the sausage manufacturing firm. The various decision areas involved were investigated and quantified for inclusion in the model. "Sausage making in the past was mostly an art, but science is now needed. . ."4/

1/ Dean, J., p. 3, (10)

2/ Snyder, J. C. and French, C. E., p. 4, (26).

3/ Dean, J., p. 3, (10).

4/ Moulton, C. R. and Lewis, W. L., p. 361, (20).

Competitive Structure

The competitive structure of the sausage processing industry is such that narrow average margins are typical for the individual firms. The earnings-to-sales ratio of 24 selected sausage manufacturers in 1962 was 1.49% compared to 1.69% in 1961 and 1.96% in 1960.[5] It is realized that these average figures are not directly applicable to any given company, but they are representative of industry profit margins. While this situation is not unique to the sausage industry, it does emphasize the difficulty management may have in maintaining profitable operations.

Intense price competition in the ingredient and finished product markets continues to exert a downward pressure on profit margins. In the ingredient market, large numbers of companies compete for available ingredients, primarily as price takers. An individual company is usually unable to influence the market price by its actions. Moreover, good sources of market price information facilitate price discovery by all firms.

In the product market price and non-price competition are important, particularly for the three top-volume products, frankfurters, bologna, and pork sausage. Varying degrees of product differentiation have permitted development of brand loyalty; yet "When prices of national brands get too high, private brands . . . emerge."[6] Quality differentiation is not so great that it can offset product prices that are much above the market level. Promotional efforts to obtain a larger share of the market must be

5/ Financial Facts About the Meat Packing Industry, 1962, p. 8, (15).

6/ Lavey, H. J., p. 119, (13).

evaluated in terms of their influence on product margins and sales volume.7/ Low profit margins and lack of strong consumer loyalty may seriously limit discretionary pricing and promotional policies. Still, management must evolve a successful marketing strategy based on maximizing company profitability.

Volume-Cost-Profit

Difference in volume and margins among the various products point up the importance to management of volume-cost-profit analysis in determining whether or not to expand production and sales or even contract them.

In sausage manufacturing, the lower-volume items normally comprising approximately 15 percent of the non-specialized firm's total volume, are traditionally the ones which have the higher margins that raise the average margin to make the entire operation profitable. A one dollar drop in sales volume of salami will require a sales increase of several dollars of franks or similar low-margin item to offset the reduced total margin.

The high-volume products, though having low per unit margins, are very important in contributing to fixed costs and thus enhance the profitability of the total operation. Moore and Jaedicke8/ emphasize that profits are affected by volume of business done, various costs, prices at which products are sold, and proportions of different products sold. Tse has stated that "The unit cost of

7/ Snyder, J. C., p. 4, (25).

8/ Moore, C. L. and Jaedicke, R. K., p. 407, (21).

a product depends upon the number of units produced and sold. This is due to the fact that different types of costs respond differently to changes in volume of operations".9/ Costs may be directly variable with volume such as meat costs, semi-variable such as operating labor costs, or fixed regardless of volume such as depreciation costs. The secretary of a leading sausage firm also recognized the importance of this relationship in a report pointing out the dependence of profit or loss on the volume of production, operating margin, and fixed costs.10/ AMI President Davison observed that "Considering the impact which volume can have on procurement costs, sales realizations and expense factors, the importance in this industry of management skill in making volume decisions can hardly be over-emphasized."11/

Functional Decision Areas

The individual functional decision areas of sausage manufacturing are closely related to overall volume-cost analysis. For purposes of this study, these individual decision areas included: formulation problems, raw material procurement, product line policy, physical facility utilization, inter-planting green materials and finished product, gang size for labor hiring, production planning, and

9/ Tse, J. Y. D., p. 68, (29).

10/ Planning for Profit, (23).

11/ Davison, H., p. 123, (9).

the general area of sales policy, particularly distribution and pricing decisions. The interrelationships of the various areas are illustrated in Figure 1.

Formulation

Formulation decisions involve determination of which available ingredients should be used in which products in what combination. "With today's present computers and the knowledge of technical people in preparing sausages, the substitutability of raw materials is great."12/ Within limits of product quality restrictions set by management policy and government regulations, it is extremely important from a cost viewpoint to get the best combination of ingredients with the lowest possible cost. Depending upon the product, ingredient costs range from 50 to 75 percent of total product costs.

The importance of this area, commonly termed least-cost formulation, is well recognized. "Modern electronic computers are widely used to control cost and quality of sausage production via a mathematical technique known as linear programming."13/ However, this area is closely interwoven with many other areas including product line, ingredient procurement, and product quality control as determined by government regulations and management specifications (Figure 1). As an example, a product line decision involving

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12/ Cox, C. B., p. 8, (8).

13/ Armbruster, W. J. and Snyder, J. C., p. 1, (2).

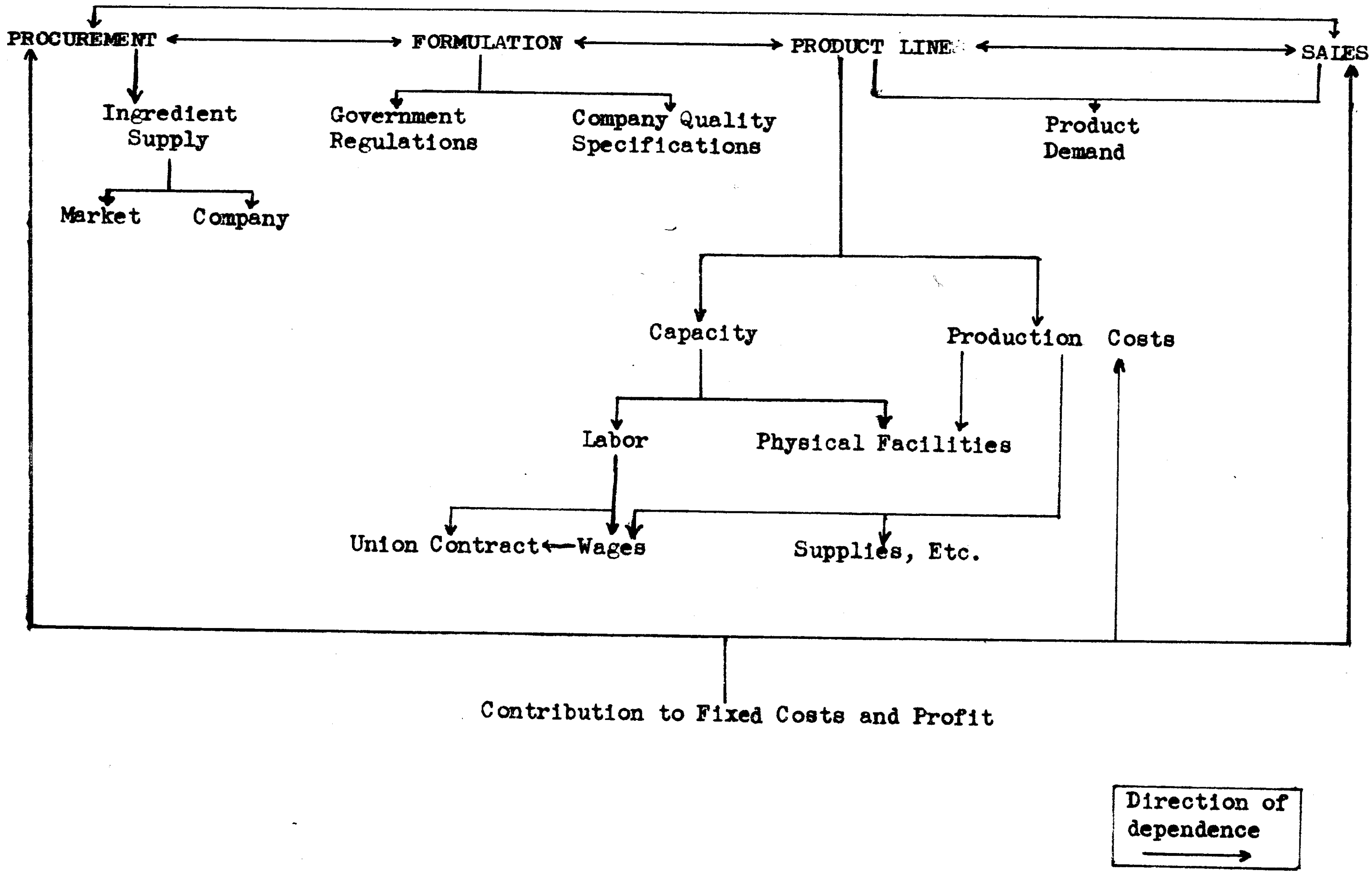

Figure 1. Functional Decision Areas as Related to Contribution to Fixed Costs and Profit of Sausage Manufacturing Firms.

an additional product may require use of a revised combination of ingredients in another product. This would release some of a material for more profitable use in the added product to obtain total production at least cost.

Ingredient Procurement

Formulation decisions are closely related to raw-material procurement practices. Generally there are several supply sources from which ingredients are available. Typically these include the car-lot national market, the local job-lot market, and materials generated from killing operations within the company. For multi-plant firms, in-company supply sources will depend upon the location of company processing plants and the related transportation structure.

Absolute and relative price relationships among ingredients are usually subject to daily or weekly changes.[14] The least cost procurement pattern is likewise subject to change but is complicated by the partial substitutability among ingredients. In addition, the different supply elasticities in alternative markets may affect least-cost patterns as the purchase volume of a given ingredient changes.

Interdivisional costing practices may also complicate buying decisions. There are several acceptable methods of by-product costing. One of the most common for ingredients, as by-products of major beef and pork killing operations, takes market value into

14/ For changes in prices of ingredients see Program Analysis Group, pp. 21-31, (24).

consideration as well as proportional weight. Ingredients ". . . are bought and sold in their green state in sufficient quantities to provide the packer with acceptable market values as a basis for allocating live cattle costs, whether he wishes to sell these parts as they are or subject them to further processing."15/

Product Line

Another major decision area may be broadly termed product line policy involving management decisions as to how many types of products to carry for maximum profit. Although it is true that other considerations play an important role in this decision area, profit maximization is the desired end result. This decision requires simultaneous consideration of raw material procurement, market demand, facility capacity, and production cost interrelationships. Sales commitments and company goals also must be given proper consideration in setting the limits on this decision area. The amount of each product directly influences variable costs and sales revenue, and hence volume-cost-profit analysis of product interrelationships is again necessary for optimization decisions.

Labor and Facilities

Physical facility and labor utilization are also closely

15/ Nickerson, C. B., p. 207, (22).

connected with volume-cost-profit considerations previously mentioned. Some specific decisions involve overtime labor, additional shift, excess capacity, and bottleneck problems. For example, it may be more profitable to run overtime at a higher wage rate for limited additional production rather than to add an additional shift with the associated minimum labor commitment. Or this increased production may not be profitable at all due to increases in supply costs and decreases in product margins. Moreover, the location of physical facility bottlenecks and resulting profit reductions also need to be investigated in making these operating decisions.

Interplanting

Interplanting decisions on green materials and finished product are important for multiple-plant sausage manufacturers. Variations in ingredient prices and availabilities among markets influence optimum procurement patterns, product line by plant, and distributive shipments. Thus, it may be feasible to ship ingredients from one location to another for processing and then return finished product to the same or other plants for selling.[16/]

16/ Perishability of products must be kept in mind here; fresh pork sausage may be held for two days at most, while franks and bologna may be held no more than 5 days. It will be assumed that finished product is in transport or in retail outlets and hence inventory problems will not be explicitly dealt with here.

In addition, profitability may be increased through specialized production at one plant of a product to be sold at all plants. These decisions would depend primarily upon plant capacities, production costs including raw materials, and related transportation charges. For firms of over five plants, the number of feasible procurement, production and distribution alternatives may be very high.17/

Sales Policy

Another major area of decision involves the closely related activities of pricing policy and sales promotional practices. As indicated earlier, the efficacy of demand estimation and demand creation are major determinants of the level of profitability.

Implicitly, pricing policy must be tied to demand elasticity by product and market area. Varying brand loyalty among products creates differences in possible pricing discretion. Packaging, personal selling, point-of-sale promotion, advertising, and technological innovation may be used to create increased product differentiation and consumer loyalty. Determining the optimum "mix" of these components of marketing strategy is the basic problem facing management. Competing firms are usually aggressive in both the price and non-price areas, and continuing pressure is also faced from the large chain store buyers.

Production Planning

Production planning must be closely tied to product sales opportunities and ingredient availabilities. Gang size, use of overtime or additional shifts, plant capacity bottlenecks and

17/ Henderson, A. and Schlaifer, R., (16).

working capital position are indicative of other areas that must be considered simultaneously. Evaluation of individual areas in a sequential manner will inevitably bring suboptimization. The high degree of interrelationship of the various areas underscores the need for simultaneous analysis if suboptimization is to be reduced.

The problem investigated in this study was profit maximization for a three-plant sausage manufacturer selling seven products in two major submarkets within each geographically limited plant market. The functional decision areas were incorporated in the model as appropriate for the operating conditions of the company.

The methodology and structure of the model will be discussed in Chapter II. Following that will be presentation of data and results of the model application in Chapter III. Finally, Chapter IV will contain a brief summary of the study and the conclusions reached.

CHAPTER II

METHODOLOGY AND MODEL STRUCTURE

Methodology

A normative model of the major decision areas discussed above was developed within the framework of linear programming. Such a model makes possible simultaneous consideration of all the interrelated alternatives in order to choose the best combination for the entire system. This is very important since the decision in any one area will be at least a partial determinant of the proper decision for one or several other areas.

In order to build and apply an accurate model based upon operating conditions and data, this analysis was undertaken as a case study of a midwestern sausage manufacturer. This permitted incorporation of accurate and consistent data into the model, even though the confidential nature of this information precludes publication of portions of the data parameters used in developing the model. Generally, this does not limit the usefulness of the model. It is sufficiently representative to be widely adopted by most sausage manufacturers in the midwest.

Use of Linear Programming

While much has been written in readily available publications[18] regarding linear programming, a brief explanation seems appropriate. Linear programming is merely an alogrithm, in this case the simplex alogrithm, for maximizing or minimizing a functional subject to linear algebraic constraints.

Algebraically the problem which may be solved by linear programming is as follows: Find values $(x_1, \ldots, x_n)$ which maximizes the linear function

$$\sum_{j=1}^{n} c_j x_j \qquad (1\text{-}1)$$

subject to the constraints

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad i=1, \ldots, m \qquad (1\text{-}2)$$

and

$$x_j \geq 0 \qquad j=1, \ldots, n \qquad (1\text{-}3)$$

18/ The following references present discussions of linear programming concepts and applications: Boulding, K. E. and Spivey, W. A. (4); Charnes, A. and Cooper, W. W. (5); Dorfman, R., Samuelson, P. A., and Solow, R. M. (11); and Ferguson, R. O. and Sargent, L. F. (14).

and where a_{ij}, c_j and b_i are constants.

As used in the model of this study, the activities of the system

$$j=1, \ldots, n \qquad (1\text{-}4)$$

represent a wide-range of business activities such as ingredient procurement, sausage formulation and finished product sales. The constraints (1-2) on these activites represent such items as limitations in plant capacity, market sales, formulation specifications and ingredient availability. The coefficients (a_{ij}) are integer or decimal values expressing production and technical relationships between activities. These coefficients relate activities to the constraints in the appropriate proportion per unit of activity.

The effect of the activities on the contribution to profit and overhead of the firm is given by c_j in the linear form

$$\sum_{j=1}^{n} c_j \, x_j \qquad (1\text{-}5)$$

where c_j represents the revenue associated with each income producing activity and costs associated with each expenditure activity. Maximization of this linear form specifies the values of each activity, $j=1, \ldots, n$, that will maximize firm profits.

Necessary Mathematical Conditions

Certain implied mathematical conditions in the use of linear programming must be met in the development of an economic model to be analyzed by the technique. An economic interpretation of these conditions is given below.

1. The business activities considered are additive in the sense that when two or more activities are carried on simultaneously, they do not complement or detract from each other.

2. The per unit output of any activity remains the same for a given resource input irrespective of the volume or level of the activity. Moreover, the input-output ratio of individual activities remains constant.

3. The business activities are divisible in the sense that resource inputs and product outputs occur in fractional units.

Structure of the Model

The model developed and tested to aid management in short-run decision making for sausage operations will be presented in greatly condensed form. This will permit discussion of each type of activity and constraint with only as much detail as is necessary to explain the structure of the model. Although one or a few activities in this condensed model may represent many more in the actual model, this reduced version contains all the important components of the model. It is of such a size that the structure and interrelationships of the various segments of the model may be readily comprehended.

Economic Parameters

The model was designed as a weekly decision model for the case study firm. It represents a three-plant firm selling 7 major sausage product lines in two major types of markets. The sausage division purchases up to 16 different ingredients from its own beef and pork divisions or from local, national or import markets. Each plant has multiple product production possibilities that are limited by plant and financial capacity and labor availability. Interplant transfer of raw materials and finished product may occur as economic considerations dictate.

Production technology is considered to be fixed for the decision making period analyzed by the model. This includes plant and equipment capacity, labor availability in terms of gang size, overtime and extra shifts, and the actual manufacturing processes used.

The firm is a price taker in the purchase of raw materials in markets that approximate conditions of perfect competition. Market prices and availabilities of raw material may fluctuate on a daily basis. Most of the 16 ingredients are available in adequate amounts at the prevailing market prices, although shortages might develop if individual utilization rates were high. In addition to the raw materials obtained from the beef and pork divisions of the firm, purchases may be made from any or all of the following sources: (1) the local job-lot market, (2) the national car-lot market and (3) the foreign import market for cowmeat and mutton. Purchases from these company units are made only if they are more attractive than open market purchases.

In the area of product sales, the firm is also essentially a price taker. Several market segments exist, however. For purposes of analysis, these are identified as market "A", market "B", and market "C". In the market "A" segment, the probability is one that a given volume of output will be sold at an established price. In the market "B" segment, the probability is less than one that an incremental volume of output will be sold at the established price. The market "B" segment also may represent the situation where the probability is one that all the incremental output will be sold at prices discounted below the market "A" level. The third market segment represents sales commitment of specified amounts to key accounts. These sales are priced at a slight discount below market "A" prices, reflecting cost savings due to volume.

The basic cost classification is such that raw material procurement and similar aggregate activities are treated as common variable costs not assigned to specific products for decision purposes. All traceable variable costs are allocated to individual products. Fixed costs are not included in the model for determining the optimal combination of activities.

The model is designed to maximize short-run contribution to profit and overhead. The actual objective, however, is assumed to be long-run maximum profits. Therefore, short-run profit maximization is bounded by long-run considerations in developing the model. Product quality specifications are an example of one important type of long-run consideration incorporated. In the short-run it may be profitable to produce a low quality product, but the long-run effect may be loss of customers who desire a higher-quality product available from competitors.

Mathematical Statement of the Model

A condensed matrix of the sausage manufacturing model is shown in Figure 2. This simplification is designed to clarify the overall structure of the model. In the actual model tested there were 727 variables representing company activities and 585 constraints on these activities. The illustrative model represents these same basic activities with only 75 structural variables and 71 constraints.

One ingredient is used to represent all ingredients available. Product formulation and production are represented by a very few activities and constraint equations for two products. Labor is in aggregate form only, but would actually be broken into enough components to represent all possibilities of overtime and additional shifts at differing wage rates. Only one of the two products is transferred through the distributive system to illustrate the technique used for all products. Finally, the volume-cost-profit analysis is also condensed by lumping all variable costs into one activity.

The mathematical statement of the model may be given as follows: Find values x_j which maximize contribution to profit and overhead

$$\sum_{j=1}^{75} c_j x_j \qquad (1\text{-}6)$$

subject to procurement, manufacturing and sales constraints

$$\sum_{j=1}^{75} a_{ij} x_j \lesseqgtr b_i \quad i = 1, \ldots, 71 \qquad (1\text{-}7)$$

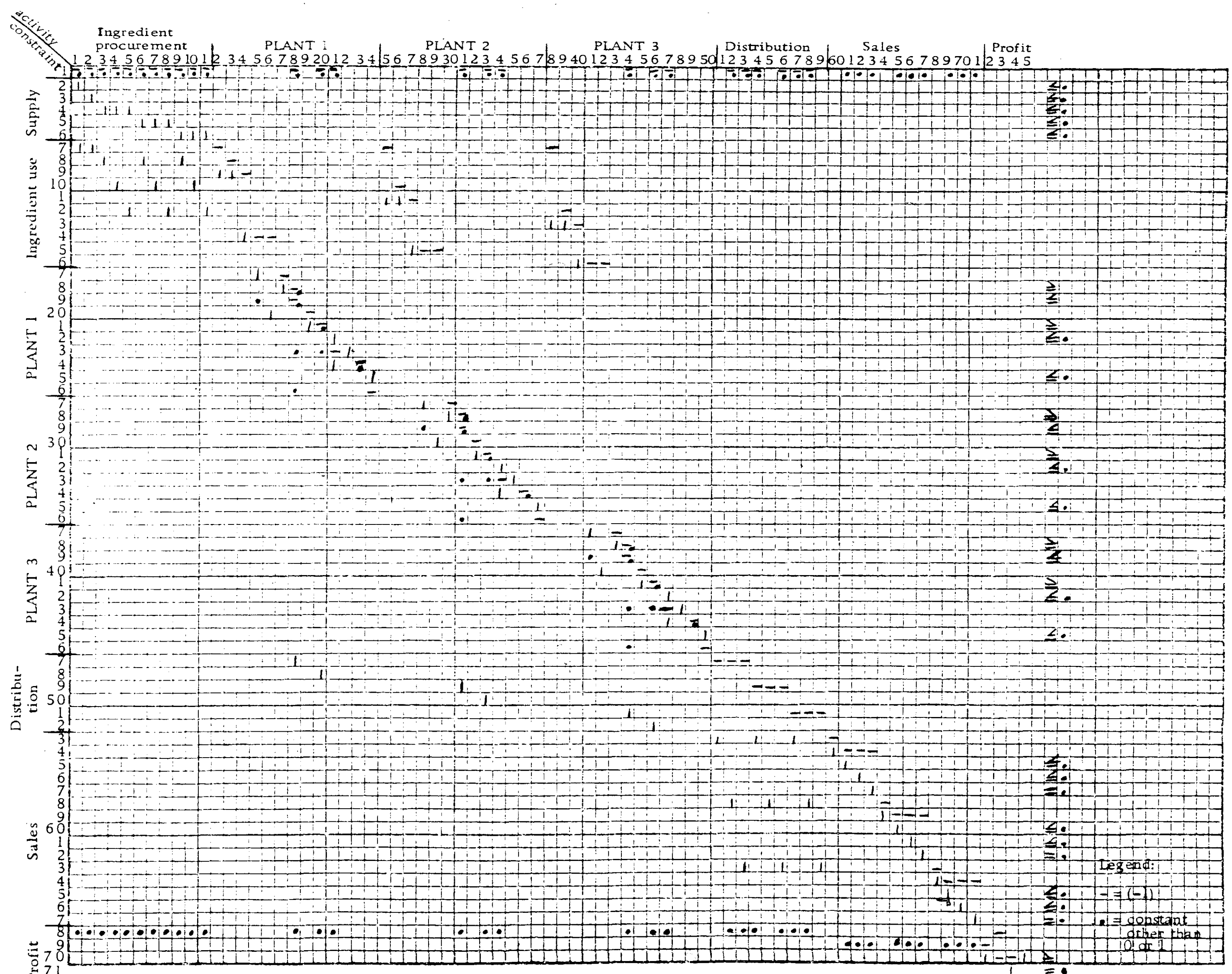

Figure 2. Condensed Matrix of Sausage Manufacturing Model.

and the non-negativity constraints

$$x_j \geq 0 \qquad j = 1, \ldots, 75 \qquad (1\text{-}8)$$

Activities of the Firm. The activities of the firm, j = 1, . . ., 75 may be classified as follows: ingredient procurement, j = 1, . . ., 11; ingredient use, j = 12, . . ., 16, 25, . . .,29, 38, . . ., 42; formulation, j = 17, . . ., 20, 30, . . ., 33, 43, . . ., 46; production, j = 21, . . ., 24, 34, . . ., 37, 47, . . ., 50; distribution, j = 51, . . ., 59; sales, j = 60, . . ., 71; volume-cost-profit summary, j = 72, . . ., 75. Each of these areas will be considered in detail.

Ingredient Procurement. Activities j = 1, . . ., 11 are ingredient purchase activities which may be explained as follows:

1. Activity j = 1 represents ingredient purchase from the national car-lot provisions market.

2. Activity j = 2 represents external market purchase on a job-lot basis from local sources.

3. Activities j = 3, 4, 5 represent purchase of ingredients from plant one slaughter to be used in plants one, two, or three. Activities j = 6, . . ., 11 represent ingredient purchase from plant two and three slaughter. The costs associated with these internal tranfer ingredient procurement activities are car-lot market prices less costs of packaging and transporting to Chicago; i.e., the cost for ingredients used at the plant produced. The cost of transportation between plants is included in the cost of materials to be shipped between plants. Thus all material procurement activities have a cost which is the cost to have the ingre-

dients at the plant, since market purchases are sold on a delivered basis.

The material procurement activities determine the optimal amount of ingredients to be obtained from each possible source. The purchase of any single type of ingredient may thus require a maximum of eleven activities. Imported ingredients require only one activity since there is no local or plant availability to consider.

Ingredient Use. Ingredient use activities, j = 12, . . ., 16 may be classified as follows:

1. Material distribution activities, j = 12, 13, 14 represent the sum of external purchases, internal transfer, and the sum of these two to determine the total amount of an ingredient available at a plant for processing. These activities do not have a cost associated with them since they are merely summation activities.

2. Material tranfer activities, j = 15, 16 likewise have no associated costs. The purpose of these activities is to allocate the total amount of an ingredient to its optimal product use. In this condensed model, regular pork trimmings are used to represent all ingredients. These activities allocate the total regulars at a plant to their two possible uses in this model, pork sausage or frank production.

Formulation. The product formulation[19] activites, j = 17,

19/ Product formulas may be flexible or fixed; a flexible formula is one in which a large number of different combinations of ingredients may be used to meet quality requirements for the product, while a fixed formula is one in which the combination of ingredients is limited to a small number of predetermined formulas.

. . ., 20 represent all the activities required to: (1) formulate flexible formula products, (2) choose the optimal formula from among several possible fixed formulas for a product, and (3) determine whether or not to produce a product having only one fixed formula. Activities j = 18, 20 represent actual determination of the optimal amounts of two products to be produced. There are costs associated with these two activities which are variable manufacturing costs other than labor and ingredient costs. They are traceable to specific products and thus may be assigned to these products.

Production. Labor utilization activities, j = 21, . . ., 23, represent labor use, including calculation of gang size to meet scheduled production needs. Facility utilization is similarly represented by x_{24}. The only cost on this group of activities is the labor wage rate since facility use costs are a part of depreciation charges included in fixed costs.

Activities j = 25, . . ., 50 for plants two and three are equivalent to activities j = 12, . . ., 24 for plant one.

Distribution. Finished product distribution activities, j = 51, . . ., 59, represent allocation of production of the various plants to the individual plant markets in which they are to be sold. The costs associated with these activities are the interplant shipping costs.

Sales. Sales activities, j = 60, . . ., 71, may be categorized as follows:

1. Activities j = 60, 64, 68 represent the total sales in each plant market.

2. Activities $j = 61, \ldots, 63, 65, \ldots, 67, 69, \ldots, 71$ represent the amounts of individual product sales in each plant submarket. Submarket "A" is the amount which is certain to be sold at the associated revenue which is the quoted market price adjusted for selling and delivery expenses since the product is being sold through the company sales division. Market "B" is the additional, uncertain amount of sales at the same market price, but applying probability as explained later, requires associating a lower revenue with the activity. Market "C" is a committed market which results from company agreements with large purchasers to take a given volume at a specified price which is \$.50/cwt. less than market "A" price.

Volume-Cost-Profit Summary. Activities $j = 72, \ldots, 75$ summarize the volume-cost-profit analysis in the model. Activity $j = 72$ is the sum of the sales revenue. Activity $j = 73$ is the sum of variable costs which include labor costs, meat costs, other variable manufacturing costs, and transportation and selling costs. Activity $j = 74$ is the contribution to profit and overhead which is determined by subtracting variable costs from sales revenue. Activity $j = 75$ is a deficit activity necessary to prevent mathematical overconstraint of the model under unfavorable economic conditions.[20]

Cost and Revenue Summary. The cost and revenue coefficients associated with the activities may be summarized as follows:

1. $c_j \leq 0$, $j = 1, \ldots, 11$ are delivered costs per hundred pounds of ingredient.

20/ See explanation on page 27.

2. $c_j \leq 0$, $j = 18, 20, 31, 33, 44, 46$ are traceable variable manufacturing costs associated with production of one hundred pounds of the product.

3. $c_j \leq 0$, $j = 21, 34, 47$ are hourly labor wage rates.

4. $c_j \leq 0$, $j = 52, \ldots, 54, 56, \ldots, 58$ are interplant shipping costs.

5. $c_j \geq 0$, $j = 61, \ldots, 63, 65, \ldots, 67, 69, \ldots, 71$ are prices at which products may be sold.

Constraints. The constraints of the firm, $i = 2, \ldots, 71$ may be classified as follows: ingredient supply limits, $i = 2, \ldots, 6$; ingredient use, $i = 7, \ldots, 16$; formulation, $i = 17, \ldots, 21, 27, \ldots, 31, 37, \ldots, 41$; production, $i = 22, \ldots, 26, 32, \ldots, 36, 42, \ldots, 46$; product distribution, $i = 47, \ldots, 52$; sales, $i = 53, \ldots, 67$; volume-cost-profit, $i = 68, \ldots, 71$.

Ingredient Supply. Constraints $i = 2, \ldots, 6$ establish an upper limit upon the supply of an ingredient from each possible source. Any amount up to maximum availability at a plant from slaughter may be used at any of the three plants. The plant's internal availability is the maximum total of: (1) the amount transferred to that plant's processing department, and (2) shipments to the processing departments of the other two plants.

Ingredient Use. The constraints for ingredient use may be classified as follows:

1. Constraints $i = 7, \ldots, 13$ control all material purchased, from either internal or external sources, for plant use. Equation 7 controls the total of ingredient purchase from outside markets for use at the three plants. Equations 8, 10 and 12 total the amount of internally transferred materials which are available to

be used at each plant. Equation 8 states that the internal material from plant one to be used at plant one, plus that at plants two and three to be shipped to one, is equal to the amount of internal supply of that ingredient to be used at plant one. Equations 9, 11, and 13 total the quantities of internally and externally purchased ingredients to get the total quantity of ingredient to be used at each plant.

2. Constraints i = 14, . . ., 16 transfer the total amount of an ingredient available at each plant to the various possible product uses which in this case are only franks and pork sausage. They assure that the total quantity procured for use at a plant equals the sum of the quantities used in various products.

Formulation. Constraints i = 17, . . ., 21 control the quality of the products. For example, constraint i = 19 controls the amount of fat permitted to be in the finished product. In the actual model, these constraints control: the amount of meat used in the product, the amounts of individual ingredients or combinations of ingredients used in the product, fat content of the product, moisture content, and the amount of spice used in the product.

All controls are in terms of percentage of finished product. For example, the fat constraint in the model states that the sum of the fat contained in the ingredients used must not constitute more than a given percent of final product. A detailed illustration of the matrix segment for a flexible-formula product formulation is given in Appendix C.

Production. Explanation of the production constraints follows:

1. Labor activities are subject to constraints i = 22, . . ., 24. Constraint i = 22 establishes the upper limit on the amount of labor which may be hired. Constraint i = 23 states that the total amount of labor hired is the amount which will be used. The coefficients for labor requirements per hundred pounds of each product determine the amount of labor to be used for each product. Since there is a minimum labor commitment, excess labor may be unused if it cannot be more profitably used after hiring. Equation 24 converts the amount of labor hired into a gang size which is needed by management in specifying the work force for the week.

2. Constraints i = 25, 26 respectively limit the amount of facility capacity and allocate its use among the products, similar to constraints i = 22, 23 for labor.

Constraints i = 27, . . ., 46 are for plants two and three the equivalent of constraints i = 17, . . ., 26 for plant one.

Distribution. Distribution of products from production to selling is regulated by equation 47, . . ., 52.

1. Equations 47 and 48 distribute plant one production of the two products to the plants at which they are to be sold, i.e., to either plant one, two, or three.

2. Equation 49, . . ., 52 distribute the production of plants two and three in the same manner.

Sales. Selling activities are constrained by i = 53, . . ., 67.

1. Equation 53 states that the total amount of product to

be sold at plant one will be the sum of: plant one product to be sold at plant one, plant two product to be sold at one, and plant three product to be sold at one.

2. Equation 54 transfers the total amount of the product to be sold at plant one to the submarkets in which it is to be sold.

3. Constraints i = 55, . . ., 57 set the maximums or committed amounts to be sold in these submarkets.

4. Constraints i = 58, . . ., 67 have the same purpose for plants two and three as do constraints i = 55, . . ., 57 for plant one.

Volume-Cost-Profit. Constraints i = 68, . . ., 71 summarize the volume-cost analysis for the sausage company as represented by the three plants.

1. Equation 68 states that total variable costs will equal the sum of labor costs, meat-ingredient costs, other variable manufacturing costs, and transportation costs.

2. Equation 69 totals the sales revenue from the operation.

3. Equation 70 summarizes a simplified operating statement including sales, variable costs, and contribution to fixed costs and profit. The inclusion of activity j = 75 associated with constraint i = 70 may be required to keep the model from being mathematically overconstrained. It allows for the very real possibility that at times it may be optimal to operate at some level even though not meeting the entire profit objective, or possibily not even completely covering fixed costs.
Thus, it may well be optimal under a given set of market

circumstances to operate at less than the minimum volume required to reach the specified level of fixed costs plus desired profit.

4. Constraint i=71 states the minimum contribution objective which will cover fixed costs and realize the desired profit. To determine the actual contribution to profit and overhead, it would be necessary to subtract any deficit from the value of i= 71. If the deficit activity is not in the optimal basis, then the contribution is given directly.

Volume-Cost-Profit Analysis

To make the model a much more useful aid, management must adapt the volume-cost-profit analysis in the model to fit the particular conditions faced by the company. Ingredient costs provide an example of possible effects of volume changes. It may be possible through promotion to slightly increase sales volume, but an increase in volume requires additional raw ingredients. If the increased volume of specific materials required does not exceed corresponding availabilities, then total material costs will vary directly with volume. Different ingredients, or a different-priced supply of the same ingredient, may be needed to produce the additional volume. Total material costs may thus increase more in total than would be expected if the costs had been directly variable as before the increase in volume. With the decrease in sales price as a result of uncertainty, and possible increase in material cost, the result is a smaller per unit contribution than would be expected with a smaller production volume. In addition, the added volume may necessitate the use of overtime labor at an increased wage rate.

The volume-cost approach to the problem permits determination of the most profitable level of overall operation. The model readily adapts to inclusion of variable costs per unit over a certain range. A second, higher per unit cost may then be used for an additional range of the same activity if this is an accurate representation of the situation within the company.

Another area where the volume-cost relationship is of importance is in the hiring of labor. A labor contract will probably exist which specifies a weekly minimum number of hours for which an employee may be paid if hired. Plant operation requires a certain minimum number of men to be available. The minimum number of employees and hours thus determine the effective minimum number of labor hours which must be paid. As explained earlier, it is not necessary that all the paid labor hours be productively used, although management may expect productive use to be more profitable under most circumstances. There also will exist a maximum number of employees which may be productively used at any one time in the plant. The labor contract will normally specify a 40 hour maximum work week at the regular wage rate. The combination of these two factors determines the upper limit on labor hours available at the regular labor rate.

Hence, labor cost is fixed up to the minimum amount which must be paid. Between the lower limit and the upper limit of labor use, the labor cost will be directly variable. Then, overtime or second shift production may be utilized at a directly variable cost, but at a higher cost rate than over the previous range of hours. Thus, one very important use of volume-cost analysis is in properly setting the constraint values in the model.

To clarify the technique of including the labor specifications in the model, consider the following illustration. Suppose that management has determined that a minimum of 10 men is needed to operate the plant and 20 men is the maximum which may be effectively used at a given time. The labor contract specificies a minimum work week of 36 hours. The maximum work week at the regular \$2 wage rate is 40 hours, and maximum overtime labor is 10 hours per week at \$3 per hour. The labor utilization rates for three illustrative products follow: franks require 1.60 hours per hundred pounds, pork sausage requires 1.20, and salami uses .90 hours/cwt.

Activities

Constraints	1	2	3	4	5	6	7	8	9	
1	–	–	–	-2.00	-3.00					
2				1						≥ 360
3				1						≤ 800
4					1					≤ 200
5				–	–	1				≤ 0
6	1.6	1.2	0.9			–	1			≤ 0
7				-.025				1		= 0
8					-.10				1	= 0

Figure 3. Model Segment for Labor Hiring and Utilization.

The numbered activities represent the following:

1. Total frank production (cwt.).
2. Total pork sausage production (cwt).
3. Total salami production (cwt).

4. Regular labor to be hired or "purchased" (hours).
5. Overtime labor to be hired (hours).
6. Total labor available (hours).
7. Excess labor hired but not utilized (hours).
8. Regular labor gang size.
9. Overtime labor gang size.

The numbered constraints may be explained as follows:

1. Profit row, here showing only the labor wage rate associated with the labor hiring activities. Traceable variable manufacturing costs for each of the products are only indicated.
2. Regular labor hired (paid) must be equal to or greater than 360 (10 x 36) hours.
3. Regular labor hired must not exceed 800 (20 x 40) hours.
4. Overtime labor hired must not exceed 200 (20 x 10) hours.
5. Total labor hours available equal the sum of regular and overtime labor hours hired.
6. Total labor utilization must be the sum of: (1.6 x cwt. of frank production), (1.2 x cwt. of pork sausage), (0.9 x cwt. of salami) and (excess of unused labor).
7. Regular gang size will equal (.025 x hours of regular labor hired), assuming that each man will be used to the 40 hour limit.
8. Overtime gang size will equal (.10 x hours of overtime labor hired), assuming full use of the 10 hour maximum for overtime.

The labor segment of the model would be handled in this manner, adapting as needed to fit the particular company and its labor contract or agreement. Second shift labor may also be considered but must be included without a minimum. The labor with the lowest wage rate will be used first; thus, analysis of second shift and overtime labor both requires separate passes, excluding one of the two each time. The resulting profitability of the two alternatives may then be compared externally to the model, simultaneously considering whether enough labor will be used to justify the minimum commitment associated with hiring a second shift.

Financial Analysis

Another area of analysis which deserves elaboration deals with the financial conditions which are of definite importance in the management decisions involved. Depending upon the financial condition of the company and existing borrowing arrangements, it may be desirable to include some type of current position ratio analysis directly in the model.[21]

To illustrate, assume a line of credit arrangement for working capital with a contract requiring that the "acid test" or "quick" ratio be maintained at a minimum level of 2.8. All borrowing must be repaid by the end of the following period. Since "acid test" ratio is defined as $\frac{\text{quick assets}}{\text{current liabilities}}$ the constraint would become $\frac{C_0 - C_1}{B} \geq 2.8$ where:
(1) C_0 represents quick assets which are cash and "near" cash such as notes currently receivable, (2) C_1 represents cash expenses payable at the end of the current period, and (3) B represents borrowing outstanding to meet cash requirements for current period.

21/ Beranek, W., p. 425, (3).

For inclusion in the model, the constraint becomes:

$$C_o - C_1 \geq (2.8)B \text{ or } C_o - C_1 - (2.8)B \geq 0.$$

When borrowing is not profitable, the ratio becomes ineffective and the constraint merely states that C_1 may not exceed C_o. The interest charge on the money borrowed may be readily included in the model and for purposes of illustration is assumed to be five percent per period.

Several assumptions are made in this analysis:

1. Cash expenses are payable by the end of the current period.
2. Due to transaction time involved in sales and processing of payment, sales revenue is not available until the end of the following period.
3. Cash receipts from the previous week's sales will be used to repay any borrowing of the previous period and build up the cash balance for the next period.
4. Beginning borrowing (B_o) may thus be assumed as zero since it must be repaid with the inflow of cash from the previous week's sales.

The following illustration demonstrates the technique of including such a constraint.

Activities

Constraints	1	2	3		
1			-.05		
2	–			=	0
3	1	–	–	$\leq$	0
4		1		=	C_o
5			1	$\leq$	B_{max}
6	–	1	-2.8	$\geq$	0

Figure 4. Model Segment for Financial Analysis.

The activities are:

1. Summation of cash expenses (C_1).
2. Quick assets at beginning of period (C_o).
3. Borrowing outstanding for one period (B).

The constraints are:

1. Profit row.
2. Total cash expenses (dollars).
3. C_1 cannot be greater than $C_o + B$.
4. Defines level of C_o.
5. Defines upper limit on line of credit if such exists; (if not, this constraint is eliminated).
6. States that $C_o - C_1 - (2.8)\ B \geq 0$ as explained above.

The ratio specified may be any other current position ratio; e.g., "current" ratio, which would be handled similarly. This type of constraint may well be imposed by management as a safety margin rather than by a creditor as a condition for borrowing. The important thing is that such an analysis be included if applicable; and if included, it should properly describe the company's particular conditions.

Input Data Uncertainty

A source of difficulties faced by management in applying such a model to actual operations is that of obtaining accurate input data. Estimating the supply functions for the ingredient markets is one of the first of these difficulties which must be faced. Moreover, the ingredients to be used must be chemically analyzed for purposes of formulation. Problems arise here because of variation in composition of ingredients obtained from different sources and from the same source in different time periods. Finally, difficulties similar to those faced in estimating ingredient supply functions are also encountered in estimating product demand functions.

As an example of a method for handling uncertainty of input data, a simplified probability method may be used for estimating demand. Assume that management has estimated that a plant has a market for at least 20,000 lbs. of franks at the market price. Sale of an additional 10,000 lbs. is possible 95 percent of the time. The market price is \$.40 per pound, implying an expected revenue of \$8,000 (20,000 x \$.40 x 1.0) for the first 20,000 lbs. produced. For the additional 10,000 lbs, the expected revenue is \$3,800 (10,000 x \$.40 x .95). This implies an expected price of $\frac{\$3,800}{10,000} = \$.38$ for this increment of production. This value is approaching the point where variable costs would not be covered for the low-margin franks. It is economically ridiculous to consider an additional increment of sales with the associated smaller probability of sale.

If the perishable product is not sold by the end of the period, it will be lost through spoilage. Thus, the effect is to reduce the average price per unit within the range of production to which a given probability pertains. This is one method of calculating the price to be included in the model for considering the desirability of producing an additional quantity of a product.

CHAPTER III

MODEL APPLICATION

The general model developed in Chapter II was adapted to the particular conditions of the case study firm and applied under four representative economic and technological conditions faced by the firm. The first phase involved determination of the optimal solution under conditions where processing capacity restricted the production level. Specifically, available plant labor consisted of predetermined gang sizes for regular and overtime labor. For the second phase, the production level was limited only by volume of product sales. Available labor, in this case, consisted of predetermined gang sizes for regular and second shift.

The next two phases analyzed differed from the second phase only in the ingredient and product price parameters. Thus, the optimal combination of activities for two-shift production capacity was analyzed under three different market price situations. Differences among these situations are representative of possible effects of weekly price changes. As such, it was possible to estimate the importance of keeping the analysis abreast of current market conditions. The other parameters were also subject to change, but were generally more stable than market prices.

Decision Guides

The model is designed for use on a decision period basis, normally a weekly period for sausage manufacturers. Prices may be expected to vary enough to require a new analysis at least weekly. The analysis should, however, be made at any time changes indicate suboptimality.

Under operating conditions, the model would normally be run on Thursday - using predicted data parameters for the forthcoming week. Alternative procurement, processing and sales plans can be evaluated in light of predicted economic conditions. Decision guides from these analyses could thus be obtained in time for the necessary action to be taken on Friday in terms of procurement, production scheduling, labor gang size and sales planning.

Due to the uncertainty problems involved with input data, managment may wish to simulate a range of economic conditions for a given decision period. Each analysis would be based upon different possible values of the input parameters. The results obtained under the different assumptions could thus be used to evaluate the sensitivity of optimal solutions.

The results of the analyses made at the end of the week may be made immediately available to management in the form of computer generated reports.[22/] This is made possible through the use of edit routines which will structure the results in a format specified by management.

The optimal solution reports must be considered as guides for management decisions rather than as final decisions for the period. A set of possible management guides obtained from the test model runs will be presented here, with actual figures where disclosure of such will not violate confidential requirements of the case firm. It is important to realize that the form of these

22/ Stafford, J. and Snyder, J. C., (27).

reports is but one possible form which could be readily designed to suit the accounting system and technical conditions for the particular firm.

In most cases, top management will be interested in aggregate cost and revenue comparisons and differences in optimal solutions at each of the plants. The production department will want only actual figures on the inputs for the products it is to process, and this information should be in a form that is directly usable by them; e.g., pounds of an ingredient per hundred pounds of a product. Those concerned with specifying gang size for the week need information regarding labor utilization. Similar guides are given for other functional areas.

In total 727 variables were used to represent the activities of the firm. These activities were controlled by 585 constraints. The structure of the model tested is similar to that given in the preceding chapter. Its exact form and related parameter data are summarized in Appendix A.

A further discussion of the input data actually used in the model test (trial) is presented below in conjunction with the decision guides obtained for phase one analysis. The results of the remaining analyses are given in Appendix B.

Procurement

The practice in this company is to make ingredient purchases from the car-lot market, the job-lot market, or from their own plants. The ingredient price used in the model is the delivered cost per cwt. of the ingredient. All car-lot purchases are in frozen form and the quantities not immediately used are transferred to freezer inventory. Ingredients are removed from freezer inventory as needed for production purposes. If the optimal solution called for purchase of less than a car lot of an ingredient and that amount were not available in freezer inventory, it would be necessary to purchase an additional car lot. The unused portion would be stored in frozen inventory for future use. If the freezer capacity were being used to the extent that no additional car-lot purchases could be stored, it would be necessary to eliminate consideration of any car-lot purchases.

Available ingredients in the job-lot market represent purchases from local sources, mostly smaller slaughtering firms unable to further process ingredients resulting from their operations. In most cases, the job-lot price is higher than car-lot and hence this market is not usually a profitable source of ingredients for this company. However, local distress supplies of job-lot ingredients may become price competitive with car-lot supplies. Moreover, delivery delays of car-lot ingredients may force purchase of job-lot fill-ins.

A smaller producer may be unable to purchase car-lot amounts because of limited production requirements and freezer space, thus narrowing his choice to plant-available or job-lot market ingredients.

The material availability from plant kill operations is determined when slaugher volume is predicted. These tranfer materials are charged at market "A" prices less the packaging and shipping costs necessary to dispose of the materials on the market. These deductions are \$.50/cwt. for beef items which are sold loose, \$1.50 for pork trimmings which are bagged, and \$2.00 for other pork items which must be boxed. The effect of pricing company-available ingredients in this manner is to determine whether it is better to use company ingredients or sell them and purchase ingredients from other sources.

The Ingredient Procurement and Utilization Guide (Table 1) shows the optimal quantities of each ingredient to obtain from the sources specified. The prices, quantities, and price ranges are given. In addition to the source from which the indicated amount of an ingredient is to be purchased, quantities to be distributed to each plant for processing are indicated.

The price ranges indicate the amount of price variation possible for one ingredient, *ceteris paribus*, without causing the optimal combination to change. The price of beef head meat in market "A" is seen to be \$28.00 per hundred which, *ceteris paribus*, could drop to \$27.50 or rise to \$28.10 without changing the combination of activities which is optimal.

Formulation

For the formulation segment of the model, confidential company data must be used for ingredient chemical analysis, product formulas and quality specifications. It is necessary to have formulas for fixed formula products and quality specifications for flexible formula products with which management is satisfied for production

Table 1. Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week I.

Ingredient	Price	Quantity	Price Range		Quantity by Processing Plant		
			Lowest	Highest	1	2	3
	$/cwt.	cwt.	dollars	dollars	cwt.	cwt.	cwt.
Market A							
Cow Meat	39.00	*	34.73	102.24	*		*
Beef Head Meat	28.00	353	27.50	28.10	148	65	140
Mutton	31.00	600	-	33.50	219	108	273
Plant 1							
Beef Hearts	21.50	57	17.54	21.50	57		
Beef Head Meat	27.50	31	-	28.00	31		
Beef Cheek Meat	32.00	76	-	32.00	76		
Plates	23.00	179	23.00	23.50	179		
Pork Cheek Meat	36.50	*	36.50	36.50	*		
Regular Pork Trmgs	25.50	4	24.65	25.50	4		
95s	40.50	*	40.08	41.29	*		*
Jowls	21.50	223	21.50	21.50	223		
Ham Fat	6.00	19	-	6.93	19		
Plant 2							
Beef Hearts	21.50	26	19.17	21.50		26	
Beef Head Meat	27.50	39	-	28.00		39	
Beef Cheek Meat	32.00	31	32.00	32.50		31	
Plates	23.00	104	21.91	23.00		104	
95s	41.50	*	41.48	42.00			*
Jowls	21.50	131	21.50	21.50		131	
Ham Fat	6.00	22	-	6.81		22	

Table 1. (Continued)

Ingredient	Price	Quantity	Price Range: Lowest	Price Range: Highest	Quantity by Processing Plant: 1	Quantity by Processing Plant: 2	Quantity by Processing Plant: 3
	$/cwt.	cwt.	dollars	dollars	cwt.	cwt.	cwt.
Plant 3							
Beef Hearts	21.50	110	21.50	21.50			110
Beef Head Meat	27.50	44	-	28.00			44
Beef Cheek Meat	32.00	107	-	32.00			107
Plates	23.00	184	21.05	23.00			184
Pork Cheek Meat	36.50	*	32.00	36.50			*
Regular Pork Trmgs	25.50	383	24.65	25.50			383
95s	40.50	*	-	41.50			*
Jowls	21.50	255	21.50	21.50			255
Ham Fat	6.00	47	6.00	6.95			47

* Confidential

and market penetration purposes.[23] The necessary figures for these purposes should be obtainable from company experience, guided by previously cited research and publications dealing with this type of data.

The Ingredient Use Guide for each plant (Tables 2, . . ., 4) specifies the total amount of meat used in the products and the formulas in terms of pounds of meat per hundred pounds of product. This latter form is useful directly for mixing batches to be processed. Note that meat cost per hundred pounds of product is also given for management's use. Formulas for flexible-formula franks, bologna, and special loaf vary in percentage oompositon as well as in meat cost per hundred pounds of product. Meat cost also varies for fixed-formula products among plants and time periods.

The Value Guide for Ingredients Not Used (Table 5) shows the penalty in profit reduction for using an ingredient not in the optimal formulas. In economic terms, this value (z_j) is the opportunity cost associated with using that ingredient, i.e., it is the incremental cost of meeting the quality restrictions by using the jth ingredient. This value is deducted from the current ingredient price to obtain the highest economically feasible price which could be paid to replace some ingredient now in the optimal production combination.

23/ For more details on formulation controls, see Appendix C.

Table 2. Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week I.

Ingredient	Total Quantity	Quantity Used in Franks		Quantity Used in Bologna		Quantity Used in New England	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*					*	*
Beef Hearts	57	28	3.7	15	4.2		
Beef Head Meat	179	112	16.4	58	16.4		
Beef Cheek Meat	76	53	7.8	9	2.4		
Plates	179	112	16.4	58	16.4		
Pork Cheek Meat	*					*	*
Regular Pork Trmgs	4						
95s	*					*	*
Jowls	223	120	17.6	83	23.5		
Ham Fat	19	19	2.8				
Mutton	219	124	18.2	71	20.3		
Total		568	82.9	294	83.2	*	*
Meat cost per cwt. of fp.			$21.23		$21.37		$40.60

Table 2. (Continued)

Ingredient	Quantity Used in			
	Salami		Special Leaf	
	cwt.	% of fp.	cwt.	% of fp.
Cow Meat				
Beef Hearts	12	23.8	2	2.2
Beef Head Meat			9	10.2
Beef Cheek Meat	13	25.8	1	1.1
Plates			9	10.2
Pork Cheek Meat				
Regular Pork Trmgs	4	7.9		
95s				
Jowls	7	13.9	13	14.8
Ham Fat				
Mutton	12	23.8	12	13.6
Total	48	95.2	46	52.1
Meat cost per cwt. of fp.		$25.75		$13.42

fp. finished product

Table 3. Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week I.

Ingredient	Total Quantity	Quantity Used in			
		Franks		Bologna	
	cwt.	cwt.	% of fp.	cwt.	% of fp.
Beef Hearts	26	5	3.8	21	4.2
Beef Head Meat	104	22	16.5	82	16.4
Beef Cheek Meat	31			31	6.2
Plates	104	22	16.5	82	16.4
Jowls	131	16	12.0	115	23.0
Ham Fat	22	22	16.5		
Mutton	108	24	18.0	84	16.8
Total		111	83.3	416	83.0
Meat cost per cwt. of fp.			$18.35		$21.37

For example, pork head meat from market "A" is priced at $28.00/cwt. and has a penalty of $2.10/cwt. profit reduction when used to replace an ingredient presently calculated to be in the optimal solution. This means that if management were to pay more than $25.90/cwt. for pork head meat, profit would be reduced from the maximum possible.

Production and Distribution

One type of data needed for this segment of the model involves the hiring and use of labor. This data is determined by labor contracts and size of physical facilities as previously discussed. For this company, the minimum work week is specified at 36 hours. The contract specifies 38.75 hours as the maximum productive time possible for regular labor, with ten hours per week being the maximum allowable overtime. Each of these

Table 4. Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week I.

Ingredient	Total Quantity	Quantity Used in Franks		Bologna		Pork Sausage	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*						
Beef Hearts	110	20	4.1	22	4.2		
Beef Head Meat	184	80	16.4	86	16.4		
Beef Cheek Meat	107	5	1.0	29	5.5		
Plates	184	80	16.4	86	16.4		
Pork Cheek Meat	*						
Regular Pork Trmgs	383					363	98.0
95s	*						
Jowls	255	74	15.2	121	23.0		
Ham Fat	47	47	9.6				
Mutton	273	100	20.5	92	17.5		
Total		406	83.2	436	83.0	363	98.0
Meat cost per cwt. of fp.			$19.74		$21.38		$24.99

Table 4. (Continued)

Ingredient	Quantity Used in					
	New England		Salami		Special Leaf	
	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*	*				
Beef Hearts			64	24.6	4	2.4
Beef Head Meat					18	10.9
Beef Cheek Meat			67	25.7	6	3.6
Plates					18	10.9
Pork Cheek Meat	*	*				
Regular Pork Trmgs			20	7.7		
95s	*	*				
Jowls			35	13.4	25	15.2
Ham Fat						
Mutton			62	23.8	19	11.5
Total	*	*	248	95.2	90	54.5
Meat cost per cwt. of fp.		$40.08		$25.74		$14.05

Table 5. Value Guide for Ingredients Not Used, Case Study Firm, 1963, Week I.

Ingredient Source	Price	Profit Reduction	Highest Feasible Price to Pay
	$/cwt.	$/cwt.	$/cwt.
Market A			
Beef Hearts	22.00	.50	21.50
Beef Cheek Meat	32.50	.50	32.00
Lean Beef Trimings	39.50	9.08	30.42
Plates	23.50	.50	23.00
Blade Meat	47.00	12.49	34.51
Pork Hearts	25.00	2.00	23.00
Pork Head Meat	28.00	2.10	25.90
Pork Cheek Meat	38.50	2.00	36.50
Regular Pork Trmgs	27.00	1.50	25.50
Special Pork Trmgs	40.50	8.50	32.00
95s	42.00	.50	41.50
Jowls	23.50	2.00	21.50
Market B			
Beef Cheek Meat	34.50	2.50	32.50
Lean Beef Trmgs	41.50	11.08	30.42
Plates	18.50	2.00	16.50
Blade Meat	48.50	13.99	34.51
Pork Hearts	28.00	5.00	23.00
Pork Head Meat	28.50	2.60	25.90
Pork Cheek Meat	40.00	3.50	36.50
Regular Pork Trmgs	27.50	2.00	25.50
Special Pork Trmgs	41.00	9.00	32.00
95s	43.00	1.50	41.50
Jowls	24.00	2.50	21.50

plants had different minimum and maximum numbers of men for efficient operation and hence different ranges of possible labor hours as given in Table 1, Appendix A. The labor utilization rates for each product are needed to properly relate the labor used per cwt. product produced. Likewise, wage rates are necessary for obtaining production costs.

The two classes of variable production costs discussed have been ingredient and labor costs. The remaining variable production costs were categorized as other variable costs. Included in this group are: employee benefits associated with direct labor, packaging supplies, storage, the variable portion of power, and the transportation involved in interplanting of products. The freight rates for product shipment are the same as those used to adjust ingredient cost and are shown in Table 2, Appendix A.

The Production and Distribution Guide (Table 6) gives the quantity of each product to be produced in the specified plant and the plant to which it should be shipped for optimal sales. For example, one pound packages of franks produced at plant one are to be sold partially in that plant's market and partially in the plant two market. The 37,000 pounds of pork sausage produced at plant three are to be sold as follows: 10,000 pounds in the plant one market, 15,000 pounds at plant two, and 12,000 at plant three. Bologna is the only product for which the optimal specifies no interplant shipping.

The Company Labor Utilization Guide (Table 7) summarizes, for each plant, the amount of labor to be hired by the company.

Table 6. **Production and Distribution Guide, Case Study Firm, 1963, Week I.**

Production		Selling Market		
Product	Quantity	Plant 1	Plant 2	Plant 3
	cwt.	cwt.	cwt.	cwt.
Plant 1				
Franks - 1 lb.	395	290	105	
Franks - 6 lbs.	287	140		147
Bologna	350	350		
New England	20	20		
Salami	50	50		
Special Loaf	88	50	38	
Plant 2				
Franks - 6 lbs.	133		120	13
Bologna	500		500	
Plant 3				
Franks - 1 lb.	487		137	350
Bologna	525			525
Pork Sausage	370	100	150	120
New England	120		75	45
Salami	260		125	135
Special Loaf	165			165

Both total labor hours and gang size are given for each of the labor categories. Plants one and three should use as much labor as possible for them to hire and plant two should hire less than the maximum number of men for even the first shift. No overtime labor is to be hired in this solution due to reasons cited earlier when discussing determination of use of second shift or overtime labor. The Plant Utilization Guide (Tables 8, . . ., 10) give the information needed by the plant managers in specifying gang sizes for the week's operations.

Information of use in a longer-run analysis may also be provided here in terms of the "shadow price."[24] This "marginal value" measures what it is worth to alter restrictions stipulated for the economic model.

24/ For additional economic interpretation see Dorfman, R., Samuelson, P. A., and Solow, R. M., p. 15, (11).

Table 7. Company Labor Utilization Guide, Case Study Firm, 1963, Week I.

	Plant 1		Plant 2		Plant 3	
Labor Category	Hours	Gang Size	Hours	Gang Size	Hours	Gang Size
Regular	813	21	727	19	1050	27
Overtime	0		0		0	
Second Shift	813	21	0		1050	27

Table 8. Plant 1 Labor Utilization Guide, Case Study Firm, 1963, Week I.

Labor Category	Hours	Gang Size
Regular	813	21
Overtime	0	
Second Shift	813	21

Table 9. Plant 2 Labor Utilization Guide, Case Study Firm, 1963, Week I.

Labor Category	Hours	Gang Size
Regular	727	19
Overtime	0	
Second Shift	0	

Table 10. Plant 3 Labor Utilization Guide, Case Study Firm, 1963, Week I.

Labor Category	Hours	Gang Size
Regular	1050	27
Overtime	0	
Second Shift	1050	27

Table 11. Labor Expansion Guide, Case Study Firm, 1963, Week I.

Labor Category	Present Limit	Value Effect	Range of Value Effect Lowest	Highest
	hours	dollars	hours	hours
Plant 1				
Regular	813	0.72	693	832
Overtime	0	-	-	-
Second Shift	813	0.62	693	832
Plant 2				
Regular	891	-	726	-
Overtime	0	-	-	-
Second Shift	891	-	-	-
Plant 3				
Regular	1050	2.10	915	1072
Overtime	0	-	-	-
Second Shift	1050	1.09	915	1072

- not economically meaningful

Thus, it measures returns obtainable per unit increase (or loss incurred per unit decrease) in the availability of a limiting factor. The associated range indicates the extremes to which the availability of the limiting factor may be changed without altering the marginal value.

The Labor Expansion Guide (Table 11), permitting a longer-run type analysis, is useful in determining dollar values (shadow prices) of more or less labor units (a limiting factor) than presently indicated. At plant three, if additional men could be used effectively, $2.10 increased profit would be made per hour of additional regular labor which would be hired up to 1072 hours. This is 22 hours more than presently possible and is less than the 36 hour minimum for an additional man. Profit could be increased at least \$2.10 x 22 = \$46.20 but since this man must be hired an additional 14 hours, further repercussions must be considered. It is impossible to precisely determine the profit effects of these 14 additional hours. The value of these additional hours will be less than \$2.10 per hour but may technically be positive, zero or negative. The maximum possible return would be \$2.09 for each of the 14 hours. The minimum possible return would be zero for each of the additional 14 hours since the model provides explicitly for unused labor without invoking a penalty. This provision is based upon management knowledge of the effect of idle labor in the plants.

Thus, the range over which the value of marginal product from increasing the gang size by one man could vary would be from a maximum of \$75.46 (\$2.10 x 22 + \$2.09 x 14) to a minimum of \$7.00 (\$2.10 x 22 + 0 x 14 - \$2.80 x 14). A more precise determination of the effects would require additional analyses with appropriate constraint changes or parametric programming.

In addition, if labor hired were reduced because the number of men indicated could not be effectively supervised, the effect of such action is similarly indicated. Labor hired could be reduced by as much as 155 hours, or by three men, and profit would be reduced by \$2.10 per hour within this range.

A Capacity Expansion Guide giving the same type of information for facilities rather than labor would also be possible. It would give a dollar value of additional facility capacity and hence would be another long-run guide since facilities are fixed in the short run. In this case, facility capacity was large enough to make such a guide unnecessary for the conditions analyzed. The plants were capable of processing approximately the following amounts of bologna in a five day week: 75,000 pounds at plant one, 100,000 pounds at plant two, and 125,000 at plant three.

Sales

The product selling prices used are adjusted market quotations for the same date as ingredient prices and are presented in Table 4, Appendix A. These prices are adjusted for variable selling and distribution costs. The assumption is that the company is a "price taker" in its product sales and will sell whatever amount possible at market price. Variation in market sales is largely influenced by nonprice competition such as product quality, advertising and other promotional means.

Generally, for low margin products (bologna, franks, and pork sausage) simplified probability is used in estimating the amounts of each product to be sold at the prevailing market price. Production in excess of the amounts of these perishable products which may be sold will lead to spoilage loss. The quantity estimates may be determined from past records and adjusted in this manner to avoid repeated over-production. Although the parameter included in this model shows a lower price for "market B", this is not in violation of the assumption of "price taking" but is merely a method of estimating the quantity to be sold.[25/]

25/ In this case, the price parameter in the model for market "B" sales is equal to market price times probability of sale; e.g., for plant one franks, 1 lb., the market price ($47.00/cwt.) times the probability of sale of an additional 9000 pounds (0.95) is equal to $44.60 ($47.00 x 0.95).

Generally for high margin products, the firm is able to sell a given quantity at a certain price and then obtain additional volume at a reduced price. Assuming that the incremental sales volume at the reduced price would not affect the original quantity and price, the model parameters for this situation may be handled exactly as in the previous economic situation. An example would be a specialty sausage item where product differentiation is more important. The company could sell 10,000 pounds at $40.00/cwt. with the possibility of selling an additional 5,000 pounds by reducing the prices for this incremental amount to $38.00/cwt.

The Plant Sales Guide by Market for each plant (Tables 12, . . ., 14) indicates the amount of each product to be sold in markets A, B, and C. In addition, the selling prices and the range over which the selling prices may vary individually without changing the optimal solution are given. This information should prove very useful in making sales decisions. One pound packages of franks could have been sold for as low as $35.81/cwt in the plant one market without changing the optimal. The lowest corresponding price in the plant two market would be $36.74/cwt., while that for the plant three market would be $35.79/cwt.

Total Sales by Product (Table 15) is a summary report for company sales information based on the various products, showing the total sales of each product and the breakdown according to market segment.

The company total is then detailed for each plant using the same classifications.

Table 12. Plant 1 Sales Guide by Market, Case Study Firm, 1963, Week I.

Product	Price	Quantity	Price Range Lowest	Price Range Highest
	$/cwt.	cwt.	$/cwt.	$/cwt.
Market A				
Franks - 1 lb.	47.00	140	35.81	-
Franks - 6 lbs.	46.00	60	34.51	-
Bologna	35.00	200	28.25	-
Pork Sausage	36.00	50	30.51	-
New England	58.50	10	45.50	-
Salami	49.00	25	31.70	-
Special Loaf	41.00	30	32.47	-
Market B				
Franks - 1 lb.	44.60	90	35.81	-
Franks - 6 lbs.	43.70	30	34.51	-
Bologna	33.20	100	28.25	-
Pork Sausage	34.20	20	30.51	-
New England	55.60	5	45.50	-
Salami	46.60	15	31.70	-
Special Loaf	39.00	15	32.47	-
Market C				
Franks - 1 lb.	46.50	60	-	-
Franks - 6 lbs.	45.50	50	-	-
Bologna	34.50	50	-	-
Pork Sausage	35.50	30	-	-
New England	58.00	5	-	-
Salami	48.50	10	-	-
Special Loaf	40.50	5	-	-

Table 13. Plant 2 Sales Guide by Market, Case Study Firm, 1963, Week I.

Product	Price	Quantity	Price Range	
			Lowest	Highest
	$/cwt.	cwt.	$/cwt.	$/cwt.
Market A				
Franks - 1 lb.	47.00	140	36.74	-
Franks - 6 lbs.	46.00	60	34.49	-
Bologna	35.00	300	28.19	-
Pork Sausage	36.00	80	30.42	-
New England	58.50	40	46.11	-
Salami	49.00	80	31.72	-
Special Loaf	41.00	20	33.40	-
Market B				
Franks - 1 lb.	44.60	80	36.74	-
Franks - 6 lbs.	43.70	20	34.49	-
Bologna	33.20	100	28.19	-
Pork Sausage	34.20	50	30.42	-
New England	55.60	25	46.11	-
Salami	46.60	35	31.72	-
Special Loaf	39.00	10	33.40	-
Market C				
Franks - 1 lb.	46.50	22	-	-
Franks - 6 lbs.	45.50	40	-	-
Bologna	34.50	100	-	-
Pork Sausage	35.50	20	-	-
New England	58.00	10	-	-
Salami	48.50	10	-	-
Special Loaf	40.50	8	-	-

Table 14. Plant 3 Sales Guide by Market, Case Study Firm, 1963, Week I.

Product	Price	Quantity	Price Range Lowest	Price Range Highest
	$/cwt.	cwt.	$/cwt.	$/cwt.
Market A				
Franks - 1 lb.	47.00	200	35.79	-
Franks - 6 lbs.	46.00	100	35.49	-
Bologna	35.00	300	27.46	-
Pork Sausage	36.00	70	29.47	-
New England	58.50	30	45.16	-
Salami	49.00	80	30.77	-
Special Loaf	41.00	100	32.57	-
Market B				
Franks - 1 lb.	44.60	100	35.79	-
Franks - 6 lbs.	43.70	30	35.49	-
Bologna	33.20	100	27.46	-
Pork Sausage	34.20	30	29.47	-
New England	55.60	10	45.16	-
Salami	46.60	40	30.77	-
Special Loaf	39.00	50	32.57	-
Market C				
Franks - 1 lb.	46.50	50	-	-
Franks - 6 lbs.	45.50	30	-	-
Bologna	34.50	125	-	-
Pork Sausage	35.50	20	-	-
New England	58.00	5	-	-
Salami	48.50	15	-	-
Special Loaf	40.50	15	-	-

Table 15. Total Sales by Product, Case Study Firm, 1963, Week I.

Product		Price	Company		Plant 1		Plant 2		Plant 3	
			Total	Market	Total	Market	Total	Market	Total	Market
		$/cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Franks - 1 lb.			882		290		242		350	
	A	47.00		480		140		140		200
	B	44.60		270		90		80		100
	C	46.50		132		60		22		50
Franks - 6 lbs.			420		140		120		160	
	A	46.00		220		60		60		100
	B	43.70		80		30		20		30
	C	45.50		120		50		40		30
Bologna			1375		350		500		525	
	A	35.00		800		200		300		300
	B	33.20		300		100		100		100
	C	34.50		275		50		100		125
Pork Sausage			370		100		150		120	
	A	36.00		200		50		80		70
	B	34.20		100		20		50		30
	C	35.50		70		30		20		20
New England			140		20		75		45	
	A	58.50		80		10		40		30
	B	56.60		40		5		25		10
	C	58.00		20		5		10		5
Salami			310		50		125		135	
	A	49.00		185		25		80		80
	B	46.60		90		15		35		40
	C	48.50		35		10		10		15
Special Loaf			253		50		38		165	
	A	41.00		150		30		20		100
	B	39.00		75		15		10		50
	C	40.50		28		5		8		15

In addition, if capacity limitations existed, it would be possible to prepare a guide evaluating costs of producing the products not chosen for the optimal solution. The minimum selling price to make profitable the production of a product for sale could be found. Thus, if the price of the product were to increase to the indicated level it would become optimal to manufacture that product. The increased production would replace production of a present product.

Information of value in a longer-run analysis is again available for product sales and is shown in the Sales Promotion Guide (Table 16). The present sales limits may possibly be altered by additional advertising or promotional efforts to increase sales. The value effect shows the gain in profit that would have occurred in this period if additional sales had been possible. The same value also indicates how much profit would have been reduced by lowering sales. This value effect applies for volume changes within the limits indicated for each product. For Market C product, management could determine the range over which such comitted sales are profitable. If the analysis shows that committed sales are consistently below the upper limit for the value effect, management may compare possible added gains with the cost of obtaining additional commitments.

Examination of these values and associated ranges, over a period of time, may indicate that a change is needed. For example, between the lower limit on the range and the present sales level, the value of additional units sold may be less than expenditures to obtain this greater volume. Thus, reduced promotional efforts

Table 16. Sales Promotion Guide, Case Study Firm, 1963, Week I.

Product		Present Sales Limit	Value Effect	Range of Value Effect Lowest	Range of Value Effect Highest
		cwt.	$/cwt.	cwt.	cwt.
Plant 1					
Franks - 1 lb.	A	140	11.19	135	200
	B	90	8.79	85	150
	C	60	10.69	55	120
Franks - 6 lbs.	A	60	11.49	55	139
	B	30	9.19	25	109
	C	50	10.99	45	129
Bologna	A	200	6.75	195	281
	B	100	4.95	95	181
	C	50	6.25	45	131
Pork Sausage	A	50	5.48	11	256
	B	20	3.68	-	226
	C	30	4.98	-	236
New England	A	10	13.00	-	34
	B	5	10.10	-	29
	C	5	12.50	-	29
Salami	A	25	17.30	20	94
	B	15	14.90	10	84
	C	10	16.80	6	79
Special Loaf	A	30	8.53	22	122
	B	15	6.53	7	107
	C	5	8.03	-	97
Plant 2					
Franks - 1 lb.	A	140	10.26	135	200
	B	80	7.86	75	140
	C	22	9.76	17	82
Franks - 6 lbs.	A	60	11.51	55	138
	B	20	9.21	15	98
	C	40	11.01	35	118
Bologna	A	300	6.81	291	444
	B	100	5.01	91	244
	C	100	6.31	91	244
Pork Sausage	A	80	5.58	41	286
	B	50	3.78	11	256
	C	20	5.07	-	226
New England	A	40	12.38	29	76
	B	25	9.48	14	61
	C	10	11.88	-	46
Salami	A	80	17.28	75	117
	B	35	14.88	30	72
	C	10	16.78	5	47
Special Loaf	A	20	7.60	12	112
	B	10	5.60	2	102
	C	8	7.10	-	100

Table 16 (Continued)

Product		Present Sales Limit	Value Effect	Range of Value Effect Lowest	Highest
		cwt.	$/cwt.	cwt.	cwt.
Plant 3					
Franks - 1 lb.	A	200	11.21	195	260
	B	100	8.81	95	160
	C	50	10.71	45	110
Franks - 6 lbs.	A	100	10.51	95	178
	B	30	8.21	25	108
	C	30	10.01	25	108
Bologna	A	300	7.53	295	379
	B	100	5.73	95	179
	C	125	7.03	120	204
Pork Sausage	A	70	6.53	31	276
	B	30	4.73	-	236
	C	20	6.03	-	226
New England	A	30	13.34	19	66
	B	10	10.44	10	46
	C	5	12.84	-	41
Salami	A	80	18.23	75	117
	B	40	15.83	35	77
	C	15	17.73	10	52
Special Loaf	A	100	8.48	92	196
	B	50	6.48	42	146
	C	15	7.98	7	111

and consequently sales would actually improve profit. Similarly, it may be determined that the profit to be gained by additional efforts to increase sales would more than cover additional costs incurred; hence, increased efforts would be desirable.

Consider the effect of increased efforts to obtain additional sales of one pound packages of franks in the plant one market. Each 100 pound increase in sales would be worth $11.19, assuming this volume increase is of a long-run nature increasing the sales amount of which management is certain. This affect will hold up to 20,000 pounds while the present limit is sales of 14,000 pounds. If the cost of obtaining added volume in this range is less than $11.19 per hundred, management would be justified in expanding promotional efforts to pick up this added volume. It must be remembered that these considerations are of a long-run nature; hence, the results from any given week may be misleading. It is necessary to examine a series of weekly results before making a decision based upon the analysis.

Operating Summary

Before the operating summary is discussed, the nature of the fixed costs included here needs elaboration. The fixed costs are broken only into two general categories for this study. Plant operating expenses include such items as: indirect labor and associated employees benefits, the fixed portion of power, depreciation, insurance, taxes, and repairs. The other class of fixed expenses contains local general, administrative, and selling expenses for the plants.

For the operation to make a profit it is necessary that enough contribution from revenue in excess of variable cost be made to surpass this fixed cost. If total revenue exceeds variable costs but not total costs, operation is desirable to reduce the loss incurred from fixed costs. Marginal revenue is then greater than marginal cost and each unit of product sold contributes something toward covering fixed cost and reducing loss.

The Estimated Operating Statement (Table 17) for the week provides management with a financial summary of the calculated optimal operations. The statement shown here involves only major categories but does highlight some of the important revenue and expense components. Meat cost is approximately 70 percent of variable costs and wages comprise more than 10 percent accounting for the two large single categories of variable expenses.

Company practice is to set a profit objective for each period. This is included in the operating statement and permits rapid evaluation of the results. In this phase, the profit contribution exceeds the profit objective.

Results of Parameter Changes

Variations in optimal solutions arising from parameter changes were examined for several economic conditions. Results of price changes and labor hiring alternatives are compared.[26]

Production Capacity

The effect of processing capacity restrictions were investigated by limiting available labor to one shift with overtime. These

[26] Ingredient prices and associated product prices are presented in Tables 3 and 4, Appendix A.

Table 17. Estimated Operating Statement, Case Study Firm, 1963, Week I.

Sales		$153,598
Meat cost		82,419
Gross margin		71,179
Variable costs:		
Wages	$12,653	
Other variable expenses	20,317	32,970
Contribution to fixed costs and profit		38,209
Fixed costs:		
Plant operating expenses	24,500	
Local selling, general and administrative expenses	8,000	32,500
Contribution to profit (loss)		5,709
Profit objective		5,300
Over (under) profit objective		$ 409

results were then compared with those where available labor consisted of two shifts.

Using Week I prices for such a comparison, Table 18 shows that hiring two shifts (Week I) is much more profitable than hiring one shift with overtime (Week Ia).[27] Two shifts resulted in a contribution to profit, after deducting fixed costs of $5,700. Use of only one shift and its allowable overtime resulted in a loss of $500, ceteris paribus. Since it is not analytically consistent to specify a minimum use level for second shift labor, the profitability of second shift versus overtime is most easily compared as in the above simulations. It must be recognized that labor union contracts specify minimum gang size for regular and second shift operations. Under the conditions analyzed, second shift operation is far more profitable than single shift with overtime. Market sales limits determine the level of production when second shift labor is available. When considering one shift with overtime, labor becomes the limiting factor. When second shift labor is available in plants one and three, plant two uses only one shift with less than the maximum number of men (23) but more than the minimum number (15).

Production capacity may become limiting in the form of either facility constraints or labor constraints. Capacity restrictions of physical facilities were not limiting for this company under present market conditions. However, for many companies facility capacity rather than sales would be the constraint effectively

27/ Detailed results for Week I are presented here in Tables 1, . . ., 17 and those for Week Ia are given in Tables 1, . . ., 7, Appendix B.

Table 18. Operating Statement Components for Alternative Labor Hiring with Week I Prices, Case Study Firm, 1963.

Component	Results	
	Week Ia	Week Ib
Sales	$131,335	$153,598
Meat Cost	71,969	82,419
Gross Margin	59,366	71,179
Wages	10.693	12,653
Other variable expenses	16,686	20,317
Contribution to fixed cost and profit	31,987	38,209
Plant operating expenses	24,500	24,500
Local selling, general and administrative expenses	8,000	8,000
Contribution to profit (loss)	(513)	5,709
Profit objective	5,300	5,300
Over (under) objective	(5,813)	409

Table 19. Procurement and Utilization of Regular Pork Trimmings as Prices Change, Case Study Firm, 1963.

Procurement		Utilization		
Source	Quantity	Plant 1	Plant 2	Plant 3
Week I				
Plant 1	4	4		
Plant 2				
Plant 3	383			383
Week II				
Plant 1	272*	272		
Plant 2	89		89	
Plant 3	585*			585
Week III				
Plant 1	272*	272		
Plant 2	302*	31	200	71
Plant 3	585*			585

*Indicates maximum amount available from plant slaughter.

limiting the level of production.

Prices

Tables 19, . . ., 23 summarize the variation of optimal solutions as cost and price parameters change, given labor availability of two shifts at all plants. Sales maximums limit the level of production for all parameter changes considered under these conditions.

Ingredients

Optimal procurement and utilization of the 16 ingredients varied greatly as parameters changed. Table 19 illustrates the changes for one selected ingredient (regular pork trimmings) as ingredient costs and product prices vary, *ceteris paribus*. Procurement and utilization of other ingredients changed in a similar manner.

In Week I, regular pork trimmings were not used to a great extent. Week II changes require purchasing all of the ingredient available from plants one and three, and all purchases are used at the plant from which they are obtained. Week three optimum indicates purchases of all the plant-available supply at each plant and shipment of parts of the quantity purchased from plant two (30,200 pounds) to plants one (3,100 pounds) and three (7,100 pounds) for processing.

Thus, interplant shipment of ingredients may be necessary for maximizing profits and the amounts of an ingredient to be purchased from a given source may vary as prices change. In addition, different quantities of a given ingredient may well be used at a plant in different price situations, even if production at each plant does not change. This latter is the case for Weeks I and II when the amounts of various products are produced at each plant but the amount of regular pork trimmings used at each plant changes quite drastically.

Meat Cost

Examination of Table 20 reveals that meat cost varies markedly as prices change. It also varies considerably among plants for a given price situation. For plant one, meat cost for franks varies from $21.23/cwt. in Week I to $16.93 in Week III. Frank meat cost variation among plants for Week I was $2.88/cwt. Week II franks show a meat cost range of $2.07 among plants and for Week III franks the range is $1.52 among plants.

Choice of different formulas and ingredient sources for production at different plants is important in terms of cost reduction. This comparison alone should do much to indicate the merits of an overall model as opposed to the "least-cost" formulation model which would choose a single formula and hence meat cost for all frank production.

If the frank formula for plant two (with meat cost of $15.41/cwt.) were used at all plants for Week III production, the total meat cost for franks would be quite different. Total frank production for the three plants is 130,200 pounds in Week III.

Table 20. Meat Cost Variation Between Plants as Prices Change, Case Study Firm, 1963.

Product	Meat Cost Plant 1 $/cwt. fp.	Meat Cost Plant 2 $/cwt. fp.	Meat Cost Plant 3 $/cwt. fp.
Week I			
Franks	21.23	18.35	19.74
Bologna	21.37	21.37	21.38
Pork Sausage			24.99
New England	40.60		40.08
Salami	25.75		25.74
Special Loaf	13.42		14.05
Week II			
Franks	18.05	15.98	16.49
Bologna	16.44	16.94	17.11
Pork Sausage			15.19
New England	37.70		37.91
Salami	23.36		23.43
Special Loaf	11.11		11.35
Week III			
Franks	16.93	15.41	15.53
Bologna	15.50	16.03	16.12
Pork Sausage			13.24
New England	37.50		37.71
Salami	22.70		22.85
Special Loaf	10.68		10.55

With the meat cost of $15.41/cwt., total meat cost for franks would be $20,065. The meat costs actually indicated for each plant would result in a total meat cost of $21,120 for franks. The optimal meat cost for franks, considering the interrelationships, is $1,050 greater than it would be if the cheapest frank formula for the week could be used at all plants. Thus, in this instance, use of frank formulas with higher meat cost was necessary to minimize total meat cost for the company.

Table 21 indicates that optimal operation may require shifting production locations even though the same total quantities of each product are produced to meet maximum sales possibilities. For Weeks I and II no production shifts are necessary. However, Week III prices cause a change in the optimal operation pattern. An additional 6,000 one-pound packages of franks are to be produced at plant one; consequently 8,300 pounds fewer of six-pound bulk packages of franks may be produced at this plant, since the maximum amount of labor available with two shifts is being used. The 8,300 pounds of bulk packaged franks previously produced at plant one would now be produced at plant two. The one-pound production added to plant one was removed from plant three.

Thus, price changes alone may effect production location. Here we have assumed that efficiency of the plants has not changed which may not be the case over a period of time. If these relationships change, they may increase or reduce amounts of production shifting. This indicates another important reason for using such a model to consider all interactions.

Table 21. Production Location as Prices Change, Case Study Firm, 1963.

Product	Production Quantity Week I	Week II	Week III
	cwt.	cwt.	cwt.
Plant 1			
Franks - 1 lb.	395	395	455
Franks - 6 lbs.	287	287	204
Bologna	350	350	350
New England	20	20	20
Salami	50	50	50
Special Loaf	88	88	88
Plant 2			
Franks - 6 lbs.	133	133	216
Bologna	500	500	500
Plant 3			
Franks - 1 lb.	487	487	427
Bologna	525	525	525
Pork Sausage	370	370	370
New England	120	120	120
Salami	260	260	260
Special Loaf	165	165	165

Labor hiring for the different weeks is summarized in Table 22. Weeks I and II require the same number of men in each plant, with plants one and three hiring the maximum number of men for both regular and second shifts. Plant two uses less than the maximum number of men on the regular shift and none for second shift work. Week III production changes previously examined necessitate changes in labor hiring. Plant one retains the maximum number of men for both shifts, while plant three maintains maximum for regular shift but drops three men from the second shift. Plant two requires the maximum number of men for regular shift but still no second shift work is to be done at that plant.

Changes in profit contribution as prices change are presented in Table 23. Total sales are seen to change little as would be expected since all sales volumes are at maximum amounts and few changes in product prices have occurred. However, the meat cost changes are large enough to result in large changes in the gross margin.

For Week I prices, the gross margin is $71,200 which compares to $82,400 for Week II prices and $85,400 for Week III prices. The profit objective is changed with each price change since ingredient cost has such an important effect upon profit contribution. The profit contribution for Week I is $5700, $15,000 for Week II, and $18,000 for Week III.

Examination of the amount by which profit contribution exceeds the profit objective, makes possible some estimate of the value of using the model. A precise determination of the profit increase attributable to the model would require comparison of

Table 22. Variation in Labor Hiring as Prices Change, Case Study Firm, 1963.

Labor Category	Gang Size			
	Maximum	Week I	Week II	Week III
Plant 1				
Regular	21	21	21	21
Second Shift	21	21	21	21
Plant 2				
Regular	23	19	19	23
Second Shift	23	0	0	0
Plant 3				
Regular	27	27	27	27
Second Shift	27	27	27	24

Table 23. Variation in Operating Statement Components as Prices Change, Case Study Firm, 1963.

Component	Week		
	I	II	III
Sales	$153,598	$149,069	$148,418
Meat cost	82,419	66,660	62,972
Gross margin	71,179	82,409	85,446
Wages	12,653	12,653	12,723
Other variable expenses	20,317	20,301	20,242
Contribution to fixed costs and profit	38,209	49,455	52,481
Plant operating expenses	24,500	24,500	24,500
Local selling, general and administrative expenses	8,000	10,000	10,000
Contribution to profit (loss)	5,709	14,955	17,981
Profit objective	5,300	13,700	16,500
Over (under) profit objective	409	1,255	1,481

results of management decisions with and without the aid of the model under actual weekly operating conditions as they may change. The purpose of this study was the development of a suitable model to fit a sausage processing firm's management decision needs and illustrate the use of such a model. However, assuming that the profit objectives used here are realistically determined upon the basis of management experience under similar conditions, it may be concluded that substantial profit increases could be expected from adapting such a model to be used in making routine operating decisions.

Computation

All model development and application was done on the IBM 7090 electronic computer using the LP/90 operating system for linear programming.[28] However, there is no reason that the model cannot be utilized with any computer and software program capable of handling the size problem which defines a firm's operations. Nor is there any necessity for a firm to own a computer and maintain a staff of linear programming experts. Computational facilities are conveniently available at a reasonable cost for most firms able to benefit from integrating such a model into their operations.

The variations presented here were all computed by using magnetic tapes to store the previous optimal solution for restarting computations. This facilitates quick, efficient calculation of the new optimum. Computation costs for the variations illustrated ranged from $85 to $140 to obtain the new optimum.

28/ Details of the system may be found in the LP/90 Usage Manual (18).

Costs could be expected to be within this range for weekly runs involving price changes for which the new optimal combination of activities would be printed into reports. This cost must be weighed against the change in profit from one week to the next to determine if weekly runs are appropriate. Smaller companies having a single plant could do a very comprehensive job of quantifying their operations with a much smaller model, substantially reducing the computational cost.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary

The competitive structure of the sausage processing industry requires careful analysis of the individual firm's alternatives to choose the best combination of activities for the company. Within the restrictions dictated by competition and society, the objective of the sausage manufacturer is to maximize contribution to fixed costs and profits. Company strategy for maximizing profitability must therefore be evolved within this framework.

Differences in volume and margins among the various products point up the importance of volume-cost-profit analysis adapted to the particular firms. The relationships of the various cost and revenue factors to volume are of extreme importance in determining the profitability of the sausage manufacturer.

The individual functional decision areas are closely related to overall volume-cost analysis. For purposes of this study, the functional decision areas considered included: formulation problems, raw material procurement, product line policy, physical facility utilization, interplanting green materials and finished product, gang size for labor hiring, production planning, and the general area of sales policy, particularly distribution and pricing decisions.

A normative linear programming model of the major decision areas was built to simultaneously consider all of the interrelated alternatives. The analysis was undertaken as a case study to permit incorporation of consistent data in the model. In addition, it permitted building the model around the type of management analysis necessary for it to be useful in an operational setting. The model tested for the case firm contained 727 variables representing the activities of the firm and these activities were controlled by 585 constraints. The model was designed as a weekly decision model representing a three-plant firm selling seven major sausage product lines in two major types of markets. The sausage division represented by this model could purchase up to 16 ingredients from job-lot, car-lot, or in-company sources.

The firm is generally a price taker in both the product and ingredient markets. Traceable variable costs are allocated to the appropriate products, whereas common variable costs are a function of total output. The model is designed to maximize the short-run contribution to fixed costs and profit. Maximization of the long-run contribution is the actual objective of the firm and this is considered in setting constraints on the short-run decisions.

Four phases were analyzed for the case firm. The first phase analyzed involved production capacity as the limiting factor. In the second phase analysis, market sales became the limiting factor, *ceteris paribus*. The third and fourth phases likewise were limited by market sales as the levels of ingredient and product prices changed. The resulting variations in the optimal solutions were then compared for the different phases.

From examination of the results obtained, it became evident that optimal patterns of operation change as conditions change. For this company, the effective limiting factor for productive capacity was labor. Operation with two shifts in two of the plants and a single shift in the other was seen to be a much more profitable situation then operating all plants with a single shift and the associated overtime.

Ingredient procurement sources and quantities of each ingredient used at the different plants changed as prices varied. As an example, for regular pork trimmings the optimal purchase quantities from the various sources ranged from zero to the maximum available as prices changed. In addition, interplant shipment of this ingredient was required in Week III but not for other weeks. The amount of the ingredient to be used at each plant also varied with different prices.

The formulas and product meat costs varied among plants within a given time period and for the same plants between the periods. For Week I, meat costs for flexible-formula franks varied from \$18.35 at plant two to \$21.23 at plant one while fixed-formula New England sausage had variation in meat cost from \$40.08 at plant three to \$40.60 at plant one. Plant three franks showed meat cost variation from \$19.74/cwt. in Week I to \$15.53 in Week III. Pork sausage produced at plant three from a single ingredient fluctuated in meat cost from \$24.99/cwt. in Week I to \$13.24 in Week III, indicating the effect of ingredient price changes upon costs of the finished product.

Production location also changed in different time periods, even though the same total quantities of products were manufactured. In the model test, production of 6,000 pounds of one-pound packages of franks was shifted from plant three in Weeks I and II to plant one during Week III. An accompanying production shift of bulk-packaged franks resulted in 8,300 pounds formerly produced at plant one being produced at plant two.

Closely related to these production shifts were changes in labor hiring. Plant one required that the maximum number of men be hired for two shifts for all weeks. Plant two used regular shift labor at less than the maximum for Weeks I and II and at the maximum level only for Week III. Plant three required the maximum number of men for regular shift work for all weeks, while the maximum second shift was indicated for only the first two weeks.

Finally, profit contribution varied widely with changing market conditions. The amount by which estimated profit contribution exceeded the profit objective in the analyses indicated the general magnitude of profit improvement attributable to use of the model. These amounts were $400 for Week I, $1,250 for Week II and $1,500 for Week III. These figures represented approximately 9 percent increases in contribution to profit above the profit objectives.

Conclusions

Use of the model to aid in making routine operating decisions for sausage manufacturing may be expected to improve profits sufficiently to warrant regular runs as data parameters change.

Although the model tested here was for a multiple-plant firm, the principles are the same for large and small firms. Purchasing, selling and the other functional decisions considered are common problems among sausage manufacturers. Smaller firms may be expected to require everything except interplanting. Deletion of this consideration from the model would greatly reduce the size of the model necessary to analyze the optimal course of action for smaller firms.

Use of the model to simultaneously evaluate interrelated decisions may be expected to substantially reduce suboptimality for the sausage manufacturers. Management of the particular firm must be able to supply the data parameters necessary for use of the model. Although this may be expected to be a source of difficulty in applying the model, it should not be an insurmountable problem. Adaptation of the data from which management presently makes decisions should prove adequate to make the model very useful.

Further Study

Possible further research that would seem appropriate includes application of operational models for various sizes of firms against actual company operation. This would allow approximation of potential profit increases from adopting such a model for regular use. Choosing the firms to be representative of each size group would expedite building models more nearly suitable for direct application by firms in each of the size groups.

Another area which is directly related and seems to offer real opportunity for contributions is that of improving methods of obtaining input data which is needed for use of the model. The present state of estimating data parameters does not permit full exploitation of the model.

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APPENDIX A

Mathematical Description of Test Model

The mathematical description of the model tested is given below.

The activities of the firm may be summarized as follows:

1. Procurement activities

$x_j \qquad (j = 1, \ldots, 154)$

2. Ingredient use activities

$x_j \qquad (j = 155, \ldots, 197, 294, \ldots, 336, 433, \ldots, 475)$

3. Product formulation and production activities

$x_j \qquad (j = 198, \ldots, 293, 337, \ldots, 432, 476, \ldots, 571)$

4. Product distribution activities

$x_j \qquad (j = 572, \ldots, 635)$

5. Product sales activities

$x_j \qquad (j = 636, \ldots, 720)$

6. Volume-cost-profit summary activities

$x_j \qquad (j = 721, \ldots, 727)$

The constraints on these activities may be stated as follows:

1. Ingredient procurement activities are limited by

$$\sum_{j=1}^{154} a_{ij}\, x_j \leq b_i \qquad (i = 1, \ldots, 70)$$

2. Ingredient use activities are controlled by

$$\sum_{j=k}^{k+42} a_{ij}\, x_j = 0 \qquad (i = 77, \ldots, 173) \quad (k = 155, 294, 433)$$

3. Product formulation and production activities are subject to

$$\sum_{j=r}^{r+95} a_{ij} x_j \gtreqless b_i \qquad (i = 174, \ldots, 262, 263, \ldots, 351,$$

$$352, \ldots, 450)$$

$$(r = 198, 337, 476)$$

4. Product distribution activities are regulated by

$$\sum_{j=572}^{635} a_{ij} x_j = 0 \qquad (i = 451, \ldots, 471)$$

5. Product sales activites are controlled by

$$\sum_{j=636}^{720} a_{ij} x_j \leq b_i \qquad (i = 472, \ldots, 577)$$

6. Volume-cost-profit summary activities are controlled by

$$\sum_{j=721}^{727} a_{ij} x_j \geq b_i \qquad (i = 578, \ldots, 585)$$

APPENDIX B

Table 1. Labor Hiring Ranges, Case Study Firm, 1963.

Limits	Gang Size	Available Hours	
		Regular Shift	Overtime
Plant 1			
Minimum	12	468	0
Maximum	21	813	210
Plant 2			
Minimum	15	540	0
Maximum	23	891	230
Plant 3			
Minimum	17	612	0
Maximum	27	1050	240

Table 2. Freight Rates Between Plants, Case Study Firm, 1963.

Origin	Freight Rate to		
	Plant 1	Plant 2	Plant 3
Plant 1		.93	.98
Plant 2	.81		1.00
Plant 3	1.04	.95	

Table 3. Ingredient Prices for Model Test, Case Study Firm, 1963.

Ingredient	Prices Sept 11, '62 Week I $/cwt.	Nov 27 Week II $/cwt.	Dec 18 Week III $/cwt.
Market A			
Cow Meat	39.00	38.50	38.50
Beef Hearts	22.00	23.75	23.50
Beef Head Meat	28.00	27.00	27.50
Beef Cheek Meat	32.50	32.50	32.50
Lean Beef Trmgs	39.50	38.00	35.00
Plates	23.50	18.50	16.50
Blade Meat	47.00	46.00	45.00
Pork Hearts	25.00	25.00	25.75
Pork Head Meat	28.00	28.00	27.00
Pork Cheek Meat	38.50	32.50	30.50
Regular Pork Trmgs	27.00	17.00	15.00
Special Pork Trmgs	40.50	36.00	34.00
95s	42.00	40.00	40.00
Sknd Jowls	23.50	11.50	11.50
Imported Mutton	31.00	29.50	27.75
Market B			
Beef Hearts	21.50	24.75	24.50
Beef Head Meat	33.00	28.00	28.50
Beef Cheek Meat	34.50	34.50	33.50
Lean Beef Trmgs	41.50	38.50	36.00
Plates	25.00	19.00	17.00
Blade Meat	48.50	46.50	45.50
Pork Hearts	28.00	25.25	26.00
Pork Head Meat	28.50	28.50	27.50
Pork Cheek Meat	40.00	34.00	31.00
Regular Pork Trmgs	27.50	17.50	15.50
Special Pork Trmgs	41.00	36.50	34.50
95s	43.00	43.00	40.50
Sknd Jowls	24.00	13.00	12.00

Table 4. Product Prices for Model Test, Case Study Firm, 1963.

Product	Prices		
	Week I	Week II	Week III
	$/cwt.	$/cwt.	$/cwt.
Market A			
Franks - 1# cello	47.00	45.00	44.50
Franks - 6# bulk	46.00	44.00	43.50
Bologna	35.00	35.00	35.00
Pork Sausage	36.00	32.50	32.50
New England	58.50	57.00	57.00
Salami	49.00	49.00	49.00
Special Loaf	41.00	39.00	39.00
Market B			
Franks - 1# cello	44.60	42.80	42.30
Franks - 6# bulk	43.70	41.80	41.30
Bologna	33.20	33.20	33.20
Pork Sausage	34.20	30.90	30.90
New England	55.60	54.20	54.20
Salami	46.60	46.60	46.60
Special Loaf	39.00	37.00	37.00
Market C			
Franks - 1# cello	46.50	44.50	44.00
Franks - 6# bulk	45.50	43.50	43.00
Bologna	34.50	34.50	34.50
Pork Sausage	35.50	32.00	32.00
New England	58.00	56.50	56.50
Salami	48.50	48.50	48.50
Special Loaf	40.50	38.50	38.50

Table 1. Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week Ia.

Ingredient	Price	Quantity	Quantity by Processing Plant 1	2	3
	$/cwt.	cwt.	cwt.	cwt.	cwt.
Market A					
Cow Meat	39.00	*			*
Beef Head Meat	28.00	267	58	96	113
Mutton	31.00	558	111	168	279
Market B					
Beef Hearts	21.50	118			118
Plant 1					
Beef Hearts	21.50	22	22		
Beef Head Meat	27.50	31	31		
Beef Cheek Meat	32.00	25	25		
Plates	23.00	89	89		
95s	41.48	*			*
Jowls	21.50	97	97		
Ham Fat	6.00	19	19		
Plant 2					
Beef Hearts	21.50	34		34	
Beef Head Meat	27.50	39		39	
Beef Cheek Meat	32.00	20		20	
Plates	23.00	135		135	
95s	41.50	*			*
Jowls	21.50	171		171	
Ham Fat	6.00	23		23	
Plant 3					
Beef Head Meat	27.50	44			44
Beef Cheek Meat	32.00	80			80
Plates	23.00	164			164
Pork Head Meat	26.00	5			5
Pork Cheek Meat	36.50	*			*
Regular Pork Trmgs	25.50	386			386
95s	40.50	*			*
Jowls	21.50	254			254
Ham Fat	6.00	47			47

Table 2. Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week Ia.

Ingredient	Total Quantity	Quantity Used in			
		Franks		Special Loaf	
	cwt.	cwt.	% of fp.	cwt.	% of fp.
Beef Hearts	22	21	4.0	1	2.8
Beef Head Meat	89	85	16.4	4	11.4
Beef Cheek Meat	25	25	4.8		
Plates	89	85	16.4	4	11.4
Jowls	97	92	17.7	5	14.3
Ham Fat	19	18	3.4	1	2.8
Mutton	111	106	20.4	5	14.3
Total		432	83.1	20	57.0
Meat cost per cwt. of fp.			$21.07		$14.07

Table 3. Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week Ia.

Ingredient	Total Quantity	Quantity Used in					
		Franks		Bologna		Special Loaf	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Beef Hearts	34	13	4.3	20	4.0	1	3.6
Beef Head Meat	135	50	16.4	82	16.4	3	10.7
Beef Cheek Meat	20	7	2.3	12	2.5	1	3.6
Plates	135	50	16.4	82	16.4	3	10.7
Jowls	171	49	16.1	118	23.5	4	14.3
Ham Fat	23	23	7.5				
Mutton	168	62	20.3	102	20.4	4	14.3
Total		254	83.3	416	83.2	16	57.2
Meat cost per cwt. of fp.			$20.21		$21.38		$14.88

Table 4. Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week Ia.

Ingredient	Total Quantity	Quantity Used in Franks		Bologna		Pork Sausage	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*						
Beef Hearts	118	2	3.8	36	4.1		
Beef Head Meat	157	4	7.6	141	16.1		
Beef Cheek Meat	80						
Plates	164	8	15.2	144	16.5		
Pork Head Meat	5	5	9.5				
Pork Cheek Meat	*						
Regular Pork Trmgs	386					363	98.0
95s	*						
Jowls	254	6	11.4	191	21.8		
Ham Fat	47	8	15.2	36	4.1		
Mutton	279	11	20.8	179	20.5		
Total		44	83.5	727	83.1	363	98.0
Meat cost per cwt. of fp.			$18.73		$20.45		$24.99

Table 4. (Continued)

Ingredient	Quantity Used in: New England cwt.	New England % of fp.	Salami cwt.	Salami % of fp.	Special Loaf cwt.	Special Loaf % of fp.
Cow Meat	*	*				
Beef Hearts			77	24.9	3	2.6
Beef Head Meat					12	10.4
Beef Cheek Meat			80	25.8		
Plates					12	10.4
Pork Head Meat						
Pork Cheek Meat	*	*				
Regular Pork Trmgs.			23	7.4		
95s	*	*				
Jowls			41	13.2	16	13.9
Ham Fat					3	2.6
Mutton			74	23.9	15	13.0
Total	*	*	295	95.2	61	52.9
Meat cost per cwt. of fp.		$40.16		$25.87		$13.02

Table 5. Production and Distribution Guide, Case Study Firm, 1963, Week Ia.

Production		Selling Market		
Product	Quantity cwt.	Plant 1 cwt.	Plant 2 cwt.	Plant 3 cwt.
Plant 1				
Franks - 1 lb.	405	200	162	43
Franks - 6 lbs.	115	115		
Special Loaf	35	35		
Plant 2				
Franks - 6 lbs.	305	25	120	160
Bologna	500		500	
Special Loaf	28		28	
Plant 3				
Franks - 1 lb.	52			52
Bologna	875	350		525
Pork Sausage	370	100	150	120
New England	140	20	75	45
Salami	310	50	125	135
Special Loaf	115			115

Table 6. Company Labor Utilization Guide, Case Study Firm, 1963, Week Ia.

	Plant 1		Plant 2		Plant 3	
Labor Category	Hours	Gang Size	Hours	Gang Size	Hours	Gang Size
Regular	813	21	891	23	1050	27
Overtime	210	21	230	23	270	27
Second Shift	0		0		0	

Table 7. Estimated Operating Statement, Case Study Firm, 1963, Week Ia.

Sales		$131,335
Meat cost		71,969
Gross margin		59,366
Variable costs:		
Wages	$10,693	
Other variable expenses	16,686	27,379
Contribution to fixed cost and profit		31,987
Fixed costs:		
Plant operating expenses	24,500	
Local selling general and administrative expenses	8,000	32,500
Contribution to profit (loss)		(513)
Profit objective		5,300
Over (under) profit objective		($ 5,813)

Table 8. Total Sales by Product, Case Study Firm, 1963, Week Ia.

Product		Price	Company		Plant 1		Plant 2		Plant 3	
			Total	Market	Total	Market	Total	Market	Total	Market
		$/cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Franks - 1 lb.			457		200		162		95	
	A	47.00		325		140		140		45
	B	44.60								
	C	46.50		132		60		22		50
Franks - 6 lbs.			420		140		120		160	
	A	46.00		220		60		60		100
	B	43.70		80		30		20		30
	C	45.50		120		50		40		30
Bologna			1375		350		500		525	
	A	35.00		800		200		300		300
	B	33.20		300		100		100		100
	C	34.50		275		50		100		125
Pork Sausage			370		100		150		120	
	A	36.00		200		50		80		70
	B	34.20		100		20		50		30
	C	35.50		70		30		20		20
New England			140		20		75		45	
	A	58.50		80		10		40		30
	B	55.60		40		5		25		10
	C	58.00		20		5		10		5
Salami			310		50		125		135	
	A	49.00		185		25		80		80
	B	46.60		90		15		35		40
	C	48.50		35		10		10		15
Special Loaf			178		35		28		115	
	A	41.00		150		30		20		100
	B	39.00								
	C	40.50		28		5		8		15

Table 9. Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week II.

Ingredient	Price	Quantity	Quantity by Processing Plant 1	2	3
	$/cwt.	cwt.	cwt.	cwt.	cwt.
Market A					
Cow Meat	38.50	*	*		*
Beef Head Meat	27.00	183	104	17	62
Mutton	29.50	600	216	119	265
Plant 1					
Beef Hearts	23.25	12	12		
Beef Head Meat	26.50	31	31		
Beef Cheek Meat	32.00	13	13		
Plates	18.00	154	154		
Pork Hearts	23.00	45	45		
Pork Head Meat	21.00	39	39		
Pork Cheek Meat	30.50	*	*		
Regular Pork Trmgs.	15.50	272	272		
95s	39.03	*	*		*
Jowls	9.50	45	45		
Ham Fat	6.00	19	19		
Plant 2					
Beef Head Meat	26.50	39		39	
Plates	18.00	104		104	
Pork Hearts	23.00	26		26	
Pork Head Meat	21.00	46		46	
Regular Pork Trmgs	15.50	89		89	
95s	38.50	*			*
Jowls	9.50	63		63	
Ham Fat	6.00	23		23	
Plant 3					
Beef Hearts	23.25	64			64
Beef Head Meat	26.50	44			44
Beef Cheek Meat	32.00	67			67
Plates	18.00	184			184
Pork Hearts	23.00	46			46
Pork Head Meat	21.08	84	5	2	77
Pork Cheek Meat	30.50	*			*
Regular Pork Trmgs	15.50	585			585
95s	38.50	*			*
Jowls	9.50	101			101
Ham Fat	6.00	47			47

Table 10. Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week II.

Ingredient	Total Quantity	Quantity Used in Franks		Bologna		New England	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*					*	*
Beef Hearts	12						
Beef Head Meat	135	102	14.8	28	8.1		
Beef Cheek Meat	13						
Plates	154	87	12.8	57	16.4		
Pork Hearts	45	28	4.1	15	4.3		
Pork Head Meat	44	10	1.5	29	8.3		
Pork Cheek Meat	*					*	*
Regular Pork Trmgs	272	207	30.4	52	15.0		
95s	*					*	*
Jowls	45			32	9.4		
Ham Fat	19			16	4.6		
Mutton	216	134	19.6	60	17.2		
Total		568	83.2	290	83.3	*	*
Meat cost per cwt. of fp.			$18.05		$16.44		$37.70

Table 10. (Continued)

Ingredient	Quantity Used in			
	Salami		Special Loaf	
	cwt.	% of fp.	cwt.	% of fp.
Cow Meat				
Beef Hearts	12	23.8		
Beef Head Meat			5	5.7
Beef Cheek Meat	13	25.8		
Plates			10	11.4
Pork Hearts			2	2.3
Pork Head Meat			5	5.7
Pork Cheek Meat				
Regular Pork Trmgs	4	7.9	9	10.2
95s				
Jowls	7	13.9	6	6.8
Ham Fat			3	3.4
Mutton	12	23.8	10	11.4
Total	48	95.2	50	56.9
Meat cost per cwt. of fp.		$23.36		$11.11

Table 11. Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week II.

Ingredient	Total Quantity	Quantity Used in			
		Franks		Bologna	
	cwt.	cwt.	% of fp.	cwt.	% of fp.
Beef Head Meat	56	15	11.3	41	8.2
Plates	104	22	16.5	82	16.4
Pork Hearts	26	5	3.8	21	4.2
Pork Head Meat	48	7	5.3	41	8.2
Regular Pork Trmgs	89			89	17.8
Jowls	63	18	13.5	45	9.0
Ham Fat	23	17	12.8	6	1.2
Mutton	119	27	20.2	92	18.4
Total		111	83.4	417	83.4
Meat cost per cwt. of fp.			$15.98		$16.94

Table 12. Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week II.

Ingredient	Total Quantity	Quantity Used in Franks		Bologna		Pork Sausage	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*						
Beef Hearts	64						
Beef Head Meat	106	54	11.3	43	8.2		
Beef Cheek Meat	67						
Plates	184	80	16.4	86	16.4		
Pork Hearts	46	20	4.1	22	4.2		
Pork Head Meat	77	25	5.1	43	8.2		
Pork Cheek Meat	*						
Regular Pork Trmgs	585	27	5.5	145	27.6	363	98.0
95s	*						
Jowls	101	51	10.7	12	2.3		
Ham Fat	47	47	9.6				
Mutton	265	100	20.5	85	16.2		
Total		406	83.2	436	83.1	363	98.0
Meat cost per cwt. of fp.			$16.49		$17.11		$15.19

Table 12. (Continued)

Ingredient	Quantity Used in: New England cwt.	New England % of fp.	Salami cwt.	Salami % of fp.	Special Loaf cwt.	Special Loaf % of fp.
Cow Meat	*	*				
Beef Hearts			64	24.6		
Beef Head Meat					9	5.5
Beef Cheek Meat			67	25.7		
Plates					18	10.9
Pork Hearts					4	2.4
Pork Head Meat					9	5.5
Pork Cheek Meat	*	*				
Regular Pork Trmgs			20	7.7	30	18.2
95s	*	*				
Jowls			35	13.4	3	1.8
Ham Fat						
Mutton			62	23.8	18	10.9
Total	*	*	248	95.2	91	55.2
Meat cost per cwt. of fp.		$37.91		$23.43		$11.35

Table 13. Production and Distribution Guide, Case Study Firm, 1963, Week II.

Production		Selling Market		
Product	Quantity cwt.	Plant 1 cwt.	Plant 2 cwt.	Plant 3 cwt.
Plant 1				
Franks - 1 lb.	395	290	105	
Franks - 6 lbs.	287	140		147
Bologna	350	350		
New England	20	20		
Salami	50	50		
Special Loaf	88	50	38	
Plant 2				
Franks - 6 lbs.	133		120	13
Bologna	500		500	
Plant 3				
Franks - 1 lb.	487		137	350
Bologna	525			525
Pork Sausage	370	100	150	120
New England	120		75	45
Salami	260		125	135
Special Loaf	165			165

Table 14. Company Labor Utilization Guide, Case Study, Firm, 1963, Week II.

	Plant 1		Plant 2		Plant 3	
Labor Category	Hours	Gang Size	Hours	Gang Size	Hours	Gang Size
Regular	813	21	727	19	1050	27
Overtime	0		0		0	
Second Shift	813	21	0		1050	27

Table 15. Estimated Operating Statement, Case Study Firm, 1963, Week II.

Sales		$149,069
Meat cost		66,660
Gross margin		82,409
Variable costs:		
Wages	$12,653	
Other variable expenses	20,301	32,954
Contribution to fixed costs and profit		49,455
Fixed costs:		
Plant operating expenses	24,500	
Local selling, general and administrative expense	10,000	34,500
Contribution to profit (loss)		14,955
Profit objective		13,700
Over (under) profit objective		1,255

Table 16. Total Sales by Product, Case Study Firm, 1963, Week II.

Product		Price $/cwt.	Company Total cwt.	Company Market cwt.	Plant 1 Total cwt.	Plant 1 Market cwt.	Plant 2 Total cwt.	Plant 2 Market cwt.	Plant 3 Total cwt.	Plant 3 Market cwt.
Franks - 1 lb.			882		290		242		350	
	A	45.00		480		140		140		200
	B	42.80		270		90		80		100
	C	44.50		132		60		22		50
Franks - 6 lbs.			420		140		120		160	
	A	44.00		220		60		60		100
	B	41.80		80		30		20		30
	C	43.50		120		50		40		30
Bologna			1375		350		500		525	
	A	35.00		800		200		300		300
	B	33.20		300		100		100		100
	C	34.50		275		50		100		125
Pork Sausage			370		100		150		120	
	A	32.50		200		50		80		70
	B	30.90		100		20		50		30
	C	32.00		70		30		20		20
New England			140		20		75		45	
	A	57.00		80		10		40		30
	B	54.20		40		5		25		10
	C	56.50		20		5		10		5
Salami			310		50		125		135	
	A	49.00		185		25		80		80
	B	46.60		90		15		35		40
	C	48.50		35		10		10		15
Special Loaf			253		50		38		165	
	A	39.00		150		30		20		100
	B	37.00		75		15		10		50
	C	38.50		28		5		8		15

Table 17. Ingredient Procurement and Utilization Guide, Case Study Firm, 1963, Week III.

Ingredient	Price	Quantity	Quantity by Processing Plant 1	2	3
	$/cwt.	cwt.	cwt.	cwt.	cwt.
Market A					
Cow Meat	38.50	*	*		*
Beef Head Meat	27.50	114	68		46
Mutton	27.75	600	226	141	233
Plant 1					
Beef Hearts	23.00	21	21		
Beef Head Meat	27.00	31	31		
Beef Cheek Meat	32.00	13	13		
Plates	16.00	175	175		
Pork Hearts	23.75	35	35		
Pork Head Meat	21.75	39	39		
Pork Cheek Meat	28.50	*	*		
Regular Pork Trmgs	13.50	272	272		
95s	39.03	*	*		*
Jowls	9.50	7	7		
Ham Fat	6.00	19	19		
Plant 2					
Beef Hearts	23.00	26		26	
Beef Head Meat	27.00	39		39	
Plates	16.00	117		117	
Pork Hearts	23.75	3		3	
Pork Head Meat	21.75	46		46	
Regular Pork Trmgs	13.82	302	31	200	71
95s	39.50	*			*
Ham Fat	6.00	23		23	
Plant 3					
Beef Hearts	23.00	74			74
Beef Head Meat	27.00	44			44
Beef Cheek Meat	32.00	67			67
Plates	16.00	174			174
Pork Hearts	23.75	33			33
Pork Head Meat	21.75	84			84
Pork Cheek Meat	28.50	*			*
Regular Pork Trmgs	13.50	585			585
95s	38.50	*			*
Jowls	9.50	35			35
Ham Fat	6.00	47			47

Table 18. Ingredient Use Guide, Case Study Firm, 1963, Plant 1, Week III.

Ingredient	Total Quantity	Quantity Used in					
		Franks		Bologna		New England	
	cwt.	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*					*	*
Beef Hearts	21			7	2.0		
Beef Head Meat	99	74	11.2	21	6.0		
Beef Cheek Meat	13						
Plates	175	108	16.4	57	16.4		
Pork Hearts	35	27	4.1	7	2.0		
Pork Head Meat	39	34	5.2	4	1.1		
Pork Cheek Meat	*					*	*
Regular Pork Trmgs	303	174	26.4	108	31.0		
95s	*					*	*
Jowls	7						
Ham Fat	19			16	4.6		
Mutton	226	132	20.0	70	20.1		
Total		549	83.3	290	83.2	*	*
Meat cost per cwt. of fp.			$16.93		$15.50	$37.50	

Table 18. (Continued)

Ingredient	Quantity Used in			
	Salami		Special Loaf	
	cwt.	% of fp.	cwt.	% of fp.
Cow Meat				
Beef Hearts	12	23.8	2	2.3
Beef Head Meat			4	4.5
Beef Cheek Meat	13	25.8		
Plates			10	11.4
Pork Hearts			1	1.1
Pork Head Meat			1	1.1
Pork Cheek Meat				
Regular Pork Trmgs	4	7.9	17	19.3
95s				
Jowls	7	13.9		
Ham Fat			3	3.4
Mutton	12	23.8	12	13.6
Total	48	95.2	50	56.7
Meat cost per cwt. of fp.		$22.73		$10.68

Table 19. Ingredient Use Guide, Case Study Firm, 1963, Plant 2, Week III.

Ingredient	Total Quantity	Quantity Used in			
		Franks		Bologna	
	cwt.	cwt.	% of fp.	cwt.	% of fp.
Beef Hearts	26	9	4.2	17	3.4
Beef Head Meat	39	15	6.9	24	4.8
Plates	117	35	16.2	82	16.4
Pork Hearts	3			3	.6
Pork Head Meat	46	10	4.6	36	7.2
Regular Pork Trmgs	200	43	19.9	157	31.4
Ham Fat	23	23	10.6		
Mutton	141	44	20.4	97	19.4
Total		179	82.8	416	83.2
Meat cost per cwt. of fp.			$15.41		$16.03

Table 20. Ingredient Use Guide, Case Study Firm, 1963, Plant 3, Week III.

Ingredient	Total Quantity cwt.	Quantity Used in: Franks cwt.	Franks % of fp.	Bologna cwt.	Bologna % of fp.	Pork Sausage cwt.	Pork Sausage % of fp.
Cow Meat	*						
Beef Hearts	74			8	1.5		
Beef Head Meat	90	48	11.2	35	6.7		
Beef Cheek Meat	67						
Plates	174	70	16.4	86	16.4		
Pork Hearts	33	17	4.0	13	2.5		
Pork Head Meat	84	22	5.2	51	9.7		
Pork Cheek Meat	*						
Regular Pork Trmgs	656	82	19.2	159	30.3	363	98.1
95s	*						
Jowls	35						
Ham Fat	47	47	11.0				
Mutton	233	69	16.2	85	16.2		
Total		355	83.2	437	83.3	363	98.1
Meat cost per cwt. of fp.			$15.53		$16.12		$13.24

Table 20. (Continued)

Ingredient	Quantity Used in New England		Salami		Special Loaf	
	cwt.	% of fp.	cwt.	% of fp.	cwt.	% of fp.
Cow Meat	*	*				
Beef Hearts			64	24.6	2	1.2
Beef Head Meat					7	4.2
Beef Cheek Meat			67	25.8		
Plates					18	10.9
Pork Hearts					3	1.8
Pork Head Meat					11	6.7
Pork Cheek Meat	*	*				
Regular Pork Trmgs			20	7.7	32	19.4
95s	*	*				
Jowls			35	13.5		
Ham Fat						
Mutton			62	23.8	17	10.3
Total	*	*	248	95.4	90	54.5
Meat cost per cwt. of fp.		$37.71		$22.85		$10.55

Table 21. Production and Distribution Guide, Case Study Firm, 1963, Week III.

Production		Selling Market		
Product	Quantity	Plant 1	Plant 2	Plant 3
	cwt.	cwt.	cwt.	cwt.
Plant 1				
Franks - 1 lb.	455	290	165	
Franks - 6 lbs.	204	140		64
Bologna	350	350		
New England	20	20		
Salami	50	50		
Special Loaf	88	50	38	
Plant 2				
Franks - 6 lbs.	216		120	96
Bologna	500		500	
Plant 3				
Franks - 1 lb.	427		77	350
Bologna	525			525
Pork Sausage	370	100	150	120
New England	120		75	45
Salami	260		125	135
Special Loaf	165			165

Table 22. Company Labor Utilization Guide, Case Study Firm, 1963, Week III.

	Plant 1		Plant 2		Plant 3	
Labor Category	Hours	Gang Size	Hours	Gang Size	Hours	Gang Size
Regular	813	21	891	23	1050	27
Overtime	0		0		0	
Second Shift	813	21	0		915	24

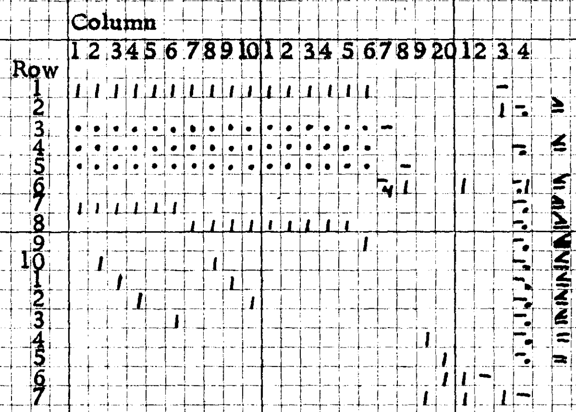
Table 23. Estimated Operating Statement, Case Study Firm, 1963, Week III.

Sales		$148,418
Meat cost		62,972
Gross margin		85,446
Variable costs:		
Wages	$12,723	
Other variable expenses	20,242	32,965
Contribution to fixed costs and profit		52,481
Fixed costs:		
Plant operating expenses	24,500	
Local selling, general and administrative expenses	10,000	34,500
Contribution to profit (loss)		17,981
Profit objective		16,500
Over (under) profit objective		1,481

Table 24. Total Sales by Product, Case Study Firm, 1963, Week III.

Product	Price	Company Total	Company Market	Plant 1 Total	Plant 1 Market	Plant 2 Total	Plant 2 Market	Plant 3 Total	Plant 3 Market
	$/cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Franks - 1 lb.		882		290		242		350	
A	44.50		480		140		140		200
B	42.30		270		90		80		100
C	44.00		132		60		22		50
Franks - 6 lbs.		420		140		120		160	
A	43.50		220		60		60		100
B	41.30		80		30		20		30
C	43.00		120		50		40		30
Bologna		1375		350		500		525	
A	35.00		800		200		300		300
B	33.20		300		100		100		100
C	34.50		275		50		100		125
Pork Sausage		370		100		150		120	
A	32.50		200		50		80		70
B	30.90		100		20		50		30
C	32.00		70		30		20		20
New England		140		20		75		45	
A	57.00		80		10		40		30
B	54.20		40		5		25		10
C	56.50		20		5		10		5
Salami		310		50		125		135	
A	49.00		185		25		80		80
B	46.60		90		15		35		40
C	48.50		35		10		10		15
Special Loaf		133		50		38		45	
A	39.00		80		30		20		30
B	37.00		35		15		10		10
C	38.50		18		5		8		5

APPENDIX C



Legend:
- = (-1)
. = constant other than 0 or 1

Figure 5. Flexible-Formula Product Formulation Matrix

Table 1. Description of Flexible-Formula Product Formulation Matrix.

Column Number	Activity Description
1	Cowmeat used.
2	Beef hearts used.
3	Beef head meat used.
4	Beef cheek meat used.
5	Lean beef trimmings used.
6	Plates used.
7	Blade meat used.
8	Pork hearts used.
9	Pork head meat used.
10	Pork cheek meat used.
11	Regular pork trimmings used.
12	Special pork trimmings used.
13	Ninety-five percent pork trimmings used.
14	Jowls used.
15	Ham fat used.
16	Mutton used.
17	Protein in product.
18	Internal moisture in product.
19	Spice in product.
20	Moisture added to product to be evaporated during smoking process.
21	Moisture added to product under control of constraint 6.
22	Total moisture added before smoking process.

Table 1. (Continued)

23	Total meat used in product.
24	Total product.

Row Number	Constraint Description
1	Meat use summation.
2	Minimum meat used.
3	Summation of protein content of ingredients used.
4	Summation of fat content of ingredients used may not exceed the stated percentage of finished product.
5	Summation of moisture content of ingredients used.
6	Moisture restriction for the product: (internal moisture) + (added moisture) = (4 x protein content) + (.10 x finished product).
7	Summation of beef ingredients used must be at least the stated percentage of total product.
8	Total pork ingredients used must be at least the stated percentage of total product.
9	Maximum percent of mutton permitted to be used.
10	Maximum percent of hearts permitted to be used.

Table 1 (Continued)

11	Maximum percent of head meat permitted to be used.
12	Maximum percent of cheek meat permitted to be used.
13	Maximum percent of plates permitted to be used.
14	Spice content of total product.
15	Moisture level for smoke house evaporation.
16	Total water added to the product shall equal the amount of added moisture permitted by constraint 6 plus the amount which will be lost in smoking the product.
17	Total product shall equal the sum of total meat used, spice used, and moisture added.