



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Swine

GIANNINI FOUNDATION OF
AGRICULTURAL ECONOMICS
LIBRARY

NOV 9 1973

**PLANNING PROBLEMS IN A
VERTICALLY COORDINATED
HOG-PORK INDUSTRY**

by

Gordon D. Honegger
and
Wilfred V. Candler



DEPARTMENT OF AGRICULTURAL ECONOMICS

Purdue University

Lafayette, Indiana

SUMMARY

This paper discusses planning of production and marketing in the hog-pork industry. Long, intermediate and short term planning problems are delineated. A linear programming model is presented which focuses on the intermediate term planning problem. It is suggested that such models are themselves part of the technology which will move the hog-pork industry away from price-coordination towards policy-coordination.

PLANNING PROBLEMS IN A VERTICALLY
COORDINATED HOG-PORK INDUSTRY

Gordon D. Honegger
Wilfred V. Candler

Purdue University, Lafayette, Indiana

INTRODUCTION

This paper discusses planning of production and marketing in the hog-pork industry. Long, intermediate and short term planning problems are delineated. A linear programming model is presented which focuses on the intermediate term planning problem. It is suggested that such models are themselves part of the technology which will move the hog-pork industry away from price-coordination towards policy-coordination.^{1/} There is little doubt that substantial changes are occurring in the hog-pork industry. These changes are likely to have a direct impact on all industry participants, including breeders, feeder pig producers, finishers, slaughterers, processors, distributors and retailers.[1] These changes are prompted both by new technological developments and, as will be emphasized in this bulletin, improved managerial planning and control procedures.

There is no consensus as to the future direction of the industry.[2] Some authorities visualize the industry following the example of the poultry industry which, for the most part, has been transformed from a traditional to an agri-business framework.[3] Others do not see any significant change in the swine-pork industry, particularly hog production, in the near future.^{2/}

The purpose of this bulletin is to examine the hog-pork industry from a broad viewpoint. We shall attempt to look at the industry in a perspective which extends from breeding stock to pork consumption. No claim is made for the exhaustiveness of this analysis. It is primarily a reconnaissance of the linkages which exist in the pork conversion process. The USDA in conjunction with several land-grant schools are currently considering undertaking a full scale research program aimed at the hog-pork subsector.[4]

This bulletin is written from a micro-economic point of view for industry participants and academicians who are looking at pork production and

marketing in a vertically coordinated framework. It does not consider the horizontal aspects of the industry, such as interregional competition or the total supply and demand for pork, hogs, or feeder pigs.[7]

A coordinated hog-pork industry is a relatively new prospect. Many firms in other agricultural industries, which are now vertically integrated, did not plan this involvement, but rather suddenly found themselves as part of a coordinated operation. Economists also failed to predict the magnitude and speed of structural change in some agricultural industries. For example, the broiler industry received some very thorough documentation after it became tightly coordinated, but not before.

This largely precluded discussion of whether the government should take steps to assist the traditional forms of poultry production. It is hoped that this bulletin will be a modest contribution towards the definition of the issues involved in any attempt to protect established methods of hog production. It asks the reader to consider the prospect of a policy-coordinated hog-pork industry at a time when, for the most part, the industry is price-coordinated.

Some of the material presented is quite detailed and complex. This is to be expected as the pork conversion process is likewise very complicated. However, planning models are becoming available which will handle this complexity, and these models themselves are a new technology which are likely to accelerate the tendency toward more policy-coordination in the industry. It is important that both decision-makers and agricultural policy-makers become aware of these models--the former to exploit them, the latter to consider the impact they might have on the structure of agriculture.[8]

PROBLEM

The application of operations research techniques to agriculture has become a recent goal of numerous economists in both academia and agribusiness. The advent of third generation computers has given economists new opportunity in building large-scale planning models.

An example is the application of planning models to the hog-pork industry. Considerable research indicates the industry suffers from some degree of suboptimization. For example, more than ten years ago a Purdue research

project^{3/} concluded that a meat-type pork product would command a price at retail high enough to compensate retailer, packer, and producer for their effort. Yet, there was no follow-up by the industry participants after the experiment.

The lack of enthusiasm for cooperative planning is not completely irrational on the part of the swine-pork industry participants. Retailers cannot mount a large-scale marketing program without some assurance that the product will be supplied.[10] Packers cannot guarantee a given quality of product without like assurances from the producers. The producers are attempting to maximize their own profits and market hogs at weights consistent with that goal [9]. Swine breeders try to breed more meatiness in hogs over time, but do not get any specific feedback from retailers, packers, or producers which will allow an optimum weighting of meatiness, versus feed conversion and other factors in a scientific breeding program.

The current structure of the industry militates against production and product planning in the manner that planning is accomplished in large firms who control their product from design to consumption.

Symptoms of the problem have been discussed and debated [10], but the dynamics of the entire process have not been put down in explicit form. This is part of the problem to which this bulletin is addressed.

Large-scale planning and control models^{4/} are a new technology in management. The problem of lack of coordination in the swine-pork industry may be improved by the use of this technology. At the very least, these models allow us to better define and understand the problem of coordination. This bulletin is a first attempt to delineate the many inter-connections in the process of converting corn to a consumer product.

THREE LEVELS OF PLANNING

In studying the coordination of the hog-pork industry at least three distinct levels of planning can be defined. There is a long term planning horizon which focuses on investment decision, such as genetic improvement, plant and equipment configurations, and consumer image creation. There is

an intermediate term planning horizon which balances strategic production and marketing decisions, such as farrowing schedules, production rates, outside purchases of feeder pigs, market hogs and primal cuts, and alternative retail marketing strategies. Finally, there is a short term planning horizon which focuses primarily on the processing and marketing functions and which synchronizes the weekly slaughter, processing and distribution of specific closely defined weight-grade groups of live hogs, primal cuts and processed pork products.

To include all three planning levels in one model would be very awkward because of size limitations and the plethora of results which would be obtained. Therefore, a choice has to be made as to the time horizon which is of primary interest. In the present study an intermediate term planning horizon was chosen because this is the area in which the problems of policy-coordination for the hog industry are likely to be felt most acutely. In the long run, the capital budgeting decisions in the hog industry are unlikely to differ markedly from parallel problems in other large industries. Due to the pioneer work of Dr. James Snyder of Purdue, and his co-workers, many of the important short term planning problems, for packers and feed companies, can already be formally coordinated with the aid of computer models.

In this bulletin, the long term (five years), intermediate term (one year) and short run (weekly) view of coordination will be presented in that order with emphasis on the intermediate term for which a prototype linear programming model has been designed.

LONG TERM

While five years in some stable industries is not considered long term, a detailed planning horizon past five years is difficult to justify in the hog-pork portion of the agricultural sector. This sector appears vulnerable to considerable change in the next decade: Competition from meat substitutes, technological changes in production and more sophisticated management techniques are at least three factors which will tend to realign competitive relationships.

What should these firms consider in attempting to plan greater coordination in the hog-pork industry? In a five year plan for coordinating this conversion process some of the important considerations are:

1. marketing
2. production
3. facilities
4. breeding
5. finance
6. research
7. personnel
8. organization

Although change toward closer coordination is unlikely to occur instantaneously throughout the industry, this discussion will center on the planning of an organization which controls the total conversion process from corn to pork.

Before discussing the planning of coordination in detail, the nature of the organization we are speaking about should be made perfectly clear. In contrast to the traditional institutional approach to production and marketing in the hog industry, we are concerned with the single price-single profit approach.

The attitude of a recent speaker at a National Pork Industry Conference is somewhat typical of the traditional view.[19] He said, "There are, in my opinion, just two groups; one being those of us who produce hogs and the other being those of you who buy, process and market pork products." A packer or a retailer could have made the same statement, that there are only two groups -- us and them. In fact, there are many groups which currently function to make up the whole hog-pork industry and in the past each has viewed his role as narrowly as the next.

By contrast this bulletin is concerned with planning from corn to retail as a single entity. This entity does not have to be a corporation; it could be a cooperative, a corporate-cooperative, a joint-venture, a series of independent firms and individuals who contract or agree verbally to a single plan. The important point is that there is a master plan, which sets the policies for and coordinates the entire pork conversion process.

Obviously, the first impulse is to look on either side of the function that a firm is now performing. For example, a meat packer might think about expanding forward into centralized retail cut processing, or backwards into hog finishing.[20] A farm supply firm might consider leasing sows, entering contract production of commercial hogs[21] or the operation of a swine breeding unit.[22]

In the following discussion we are assuming that the decision makers are interested in planning the total process of converting corn to pork. While the discussion of the master plan does not necessarily need to begin with the market plan, in a market-oriented economy, this is a logical first step.

Marketing Considerations

Coordinated production implies the development of a long-term consumer marketing plan. Such plans do not exist in the hog-pork industry today. Within the present market coordinated structure, retailers must sell to consumers what is available for them to buy. Processors must sell to retailers what producers bring to them. Producers sell to processors only the product of what they can buy from breeders. Breeders are not getting feedback from consumers, retailers, processors, and producers as to the performance of their breeding policies. Thus, unlike a manufacturing firm which simultaneously designs a product and selects a specific market segment, the process of converting corn to pork is operating without a "master plan". Everyone is trying to do a better job in his function; however, the linkages between functions are quite loose, resulting in an environment in which a long-term marketing plan is simply not feasible. Prices for breeding stock, live hogs, primals, and retail product provide some guidance for production decisions within the present structure. They signal, however, where we have been in the past, rather than where we plan to go in the future.

The considerations which enter into a long-term marketing plan for pork are similar to those used by firms who research, design, manufacture, distribute, and merchandise their own products. Most of these firms are market-oriented. That is, they first analyze a need before making a product to serve that need.

While each coordinated production-marketing organization would want to analyze the needs of the specific consumers it serves, there is some general information available as a result of public research on pork consumers.

A recent study draws these conclusions about pork and pork products:

Smoked or cured pork -- generally known as "ham" to consumers -- was found to share many of the favorable characteristics attributed to beef, and to be relatively free also from negative associations. The chief disadvantages cited concerned its keeping qualities when raw and being a meat one tires of.

Fresh pork, although reportedly eaten more often than ham, projected a less favorable image. Although respondents themselves tended to characterize fresh pork as tasty, many may have been unsure that others like its taste, as indicated by their reaction to the idea of serving pork cuts to guests whose preferences are not known. In addition to receiving the unfavorable comments mentioned above for ham, fresh pork was also often considered difficult to digest, not always safe to eat, and to have too much waste. Many also claimed that pork is not good to eat cold and does not keep well before cooking.[23]

The image of pork is not as positive as that of beef and chicken, overall. From the same survey, the following tabulation, based on the total favorable and unfavorable are respondents assigned to each meat, provides a summary of the comparative standings of these meats.

Table 1. Consumer Meat Choices

	Average Number of Choices for Each Meat			
	<u>Beef</u>	<u>Chicken</u>	<u>Ham</u>	<u>Pork</u>
Favorable	7.8	6.6	4.5	3.1
No Choice	5.6	6.3	7.4	7.5
Unfavorable	<u>.6</u>	<u>1.1</u>	<u>2.1</u>	<u>3.4</u>
Total	<u>14.0</u>	<u>14.0</u>	<u>14.0</u>	<u>14.0</u>

Despite the above attitudes there is little question about the permanency of pork in the diet of Americans.

According to many authorities, pork quality needs to be improved. Quality in pork is a somewhat vague concept. There are no government grades for retail pork as there are for beef. Nevertheless, many research findings point to the fact that consumers do differentiate among pork products and many will pay more for some meat-type pork cuts.

Results of consumer studies generally indicate that lean cuts sell better. Several small tests of hams in Iowa[24] and a large sales test of shank ham portions and loins in Missouri[25] found that lean cuts were purchased at a 3:2 ratio compared with regular cuts. However, a study by Purdue researchers found that lean center cut chops and loin roasts sold no better than well-trimmed cuts from fatter hogs.[26]

Thus, the answer to the question "Will consumers pay a price premium for lean cuts?" must be qualified. For some cuts, such as chops and loins, trimming and selling at a premium price seems profitable. On the other hand, for other cuts, such as picnics and hams, a lean quality product may only be derived from a high quality hog. Such an animal is often not available in large quantities on a regular monthly basis.

A certain marketing plan may accentuate or reduce the need for a coordinated approach. For example, a system which places high emphasis on sausage and processed pork products may not need a coordinated approach as much as one which emphasizes fresh pork products. Obviously, in a former case, the consistency and quality of the raw product has less interrelationship with the consistency and quality of the final product. On the other hand, a program which specializes in marketing portion controlled fresh pork cuts to institutional consumers may find a large benefit in coordinated breeding, production, and processing.

The implication for a long-term coordination model is that feasible marketing strategies must be defined which delineates those market segments which are to be served with specific qualities of pork products. No one system can supply all market segments with all pork products all the time. Nor can a pork system constantly make major changes in market segments which it hopes to serve. Without an explicitly defined set of consumer market strategy alternatives, a plan to coordinate the pork conversion process would be meaningless.

Production

Assuming that markets for particular kinds of pork cuts exist, the critical bottleneck is obtaining hog supplies on a consistent basis to meet the market demand.

Coordination does not necessarily require large volume. After all, the earliest forms of hog production were fully coordinated since the hogs were butchered and consumed on the same farm.

The focus of this discussion, however, is off-farm coordination. There are at least four volume levels of off-farm coordination which would be possible in the pork industry. First, individual producers can coordinate their production with local locker plants and, in turn, with local consumers. This is a very low volume (100-500 head) system of coordination, but one which exists in rural areas. Second, there are local integrators, usually feed dealers, who coordinate the production of several farmers (500-5000 head) through a single packer, and sometimes carry this coordination through to a specific market. This is a local or cluster approach. Third, there are state-wide organizations (generally cooperative) who coordinate large numbers of hogs (5000-1,000,000 head), but currently there are no examples of this type of coordination reaching to retail. Fourth, there is the possibility of a regional approach in which the larger agribusinesses (packers, assemblers, feed firms, cooperatives) coordinate hogs (100,000-1,000,000 head) throughout a multi-state geographical area.

While these four categories of coordination can be defined for discussion purposes, the percentage of U.S. hog production moving through each is as yet undefined. Useful estimates of the magnitude of coordination in the hog-pork industry have been provided by Wilbur Jenny. [27]

Two factors which give rise to speculation and conjecture about increased controlled production is the movement to confinement production facilities and the potential of estrous control in scheduling the farrowing operation. Increasingly, the traditional bottleneck in the production of hogs, the farrowing function, is becoming a scientific process. This farrowing function re-

mains as the major problem in any scheme to coordinate large numbers of hogs. Conception rate, litter size, litter weight, and disease are four key variables which are vital to efficiency and yet very difficult to manage on a large scale at this point in time.^{5/}

Buildings and Facilities

The increased value of land as a result of continuous corn production, together with the scarcity and cost of high quality labor, and combined with the increasing need for volume have created an incentive to substitute capital for labor by moving the production aspect of the hog business indoors.

The simultaneous availability of these facility innovations -- slotted floors, partially controlled environment by building enclosure, insulation and ventilation, and reduced number of hogs per pen -- have made possible the grouping of small numbers of hogs without increasing labor requirements. And the traditional disadvantages of enclosed production -- high humidity and rapid building deterioration -- have been partially eliminated by the slotted floors which made a better controlled environment feasible.[12]

To build the most modern facilities and insert the most labor saving equipment, however, requires a commitment and capital that many producers operating on an independent basis do not possess.

For example, the investment in sow capacity for a confinement system with farrowing crates and a slotted floor with pit is almost twice that of the investment required for a more traditional operation using individual outside houses. The investment was budgeted to be \$391 and \$202, respectively, in a Purdue study published in 1967.[13]

The same comparison is even more dramatic in swine finishing. This same study budgeted the investment per hog in an enclosed slotted floor finishing house to be \$46, compared to an investment of \$16 in pasture portable houses, almost a three-fold increase.[12]

However, even with the greater investment cost, the conclusion of the Purdue research is that these modern facilities create an opportunity for hog producers to further substitute capital for labor without increasing total cost of production; but also without a noticable reduction in the total cost of production.

The building and equipment configuration is the problem which is generally given the most consideration by expansion-minded investors in the swine industry. Greater efficiency of labor[14], especially with regard to the economics of manure disposal[15], is a major consideration in planning new facilities.^{6/} Since most facilities are single purpose buildings, the decision tends to be irrevocable and very high risk in terms of technological obsolescence.

Breeding Considerations

A corollary to the quantity problem in a coordinated approach to hog-pork production is obtaining a quality product. Since inheritance is responsible for up to one-half of the heterogeneity which exists in hogs, any serious attempt at creating a differentiated fresh pork product at retail must control the genetic base.

Even with a single breeding herd supplying all the breeding stock, genetic variation is still a problem. If artificial insemination ever becomes practical, it will be easier to reduce this genetic variation. The most valuable genetic traits however, are still numbers weaned per litter, and conception rate.

Thus the difficult task of choosing from among various lines of genetic material will not diminish but will increase in importance. It is this selection decision which illustrates best the opportunities of a broad vertical perspective in the hog-pork industry. In varying degrees, the selection decision influences farrowing, feeding, slaughtering, processing, and retailing efficiency. However, there are some tradeoffs inherent in this selection process: larger hams are not necessarily the easiest to retail, extreme meatiness can limit pork tenderness and may be associated with pse, and reproductive efficiency has a very high economic value but this trait is very low in heritability. Thus information feedback from all functions in the conversion process are vital to a sophisticated breeding program designed to avoid suboptimization.

It is likely that a coordinated entity would maintain control over a breeding unit which multiplies genetic stock, but this entity may not maintain a basic research program since such programs are very expensive and subject to economies of scale.

Financial Considerations

There is considerable total risk in any hog-pork coordination effort, caused not only by hog price fluctuations but also by threat of disease and technological obsolescence of fixed investments in specialized buildings and equipment.

A coordinated approach would contain some risk-reducing elements, however, particularly the potential for cost saving, increased market penetration and resource sharing among the various functions of the process. The coefficient of variation of income for a coordinated system would inevitably be smaller than the coefficient for individual members of the traditional market form of organization.

A basic financial relationship for the consideration of coordinated hog production is that each hog produced is likely to produce about \$100 of retail sales and to require a total investment of about \$100.^{7/} Also, three-fourths of the total assets employed would be fixed assets. (This is assuming a highly capitalized system is budgeted, one which takes advantage of most recent labor-reducing technology.) Thus, a 200,000 hog enterprise would involve about a \$20 million investment of which \$15 million would be fixed investment.

From these rough figures one can readily understand the major financial obstacle to rapid expansion in a coordinated hog-pork entity, the low ratio of sales to fixed assets. Such an enterprise would need as high a return on sales as investment. With a coordinated approach, a premium pork market might be developed which could support profits at this level or higher. But the financial obstacle is to obtain the long-term capital necessary to build market penetration and organizational efficiencies.

Since vertically coordinated pork conversion systems have not yet been established on any substantial scale, capital invested in such a scheme is likely to be considered venture capital and would require a high price commensurate with the risk. The steps to achieve full coordination are known; but the value of this type of association remains a matter of speculation.

Information and Research

The individual subsystems of the hog-pork industry have been, and are, well researched and developed by industry and the land-grant colleges. The accuracy with which signals are transferred from one subsystem to the next

has received much less attention, but the work which has been done suggests considerable loss of information between, and even within, firms engaged in hog and pork production.[28,29,30] The stochastic aspects of optimum systems utilization have not been extensively studied, so that yard sticks are not available to measure this aspect of current sub-sector performance.

Within a fully coordinated system total cost information would be available at retail and values established at retail could be accurately transferred back through the production process to allow slaughtering, finishing, farrowing and even breeding decisions to be synchronized with these values. The proto-type decision model discussed in this paper illustrates one way this information could be transferred within a single organization. It should be noted, however, that the generation of pertinent information can be quite expensive.

This information would also allow research and investment priorities to be set so as to remove the bottlenecks which are most important to the system as a whole.

The Personnel Plan

Appropriate personnel would be vital to any coordination arrangements of reasonable volume. It has already been pointed out that for every 10,000 hogs to be sold each year, an investment of the order of a million dollars would be required. Thus, just in terms of the scale of assets being managed, significant managerial talent is required. This is not all, to keep ahead of the game at least one policy maker probably requires a Ph. D. level of appreciation of new developments in nutrition, breeding, swine physiology and disease control. At the same time a coordination system needs to be implemented which will allow the information available to a policy coordinated system to be produced and used. These are not insignificant requirements.

In addition, personnel have to be found to actually produce the hogs. Depending on the authority, 3,000 to 6,000 hogs per man per year appears currently to be the upper limit of productivity which can be envisaged. This implies a large number of men.

Men who can manage the complex problems involved in breeding, farrowing, and finishing large numbers of hogs are mostly already successfully employed on their own account. The alternative of hiring college-trained management may eventually be a viable one, but experience so far would indicate that the most

successful swine producing systems are the result of a man growing with his mistakes over time, and on the same farm. [31]

The profit differences between poorly managed and well managed swine enterprises emphasizes the critical importance of this factor. [32,33]

An Organizational Plan

An organizational plan is the most critical of all the long-term problems. There are few, if any, American firms who are currently involved in all the functions of the pork conversion process on any substantial scale. If a single plan covering the entire pork conversion process is to be effected, two or more firms will need to act as one, or substantial expansion of current areas of managerial control will have to be implemented. The latter is likely to be expensive, while the former is very difficult to achieve, particularly between firms who have traditionally viewed each other as "enemies".

Armstrong and Schneidau suggest the kind of activities which need to be considered in an organizational plan, [34](these activities are particularly important if the organization is of a contractual form). They classify these functions as: primary activities, facilitating services, and service and supply inputs.

A. Primary Activities

1. Producing breeding stock
2. Feeder pig production
3. Slaughter hog production
4. Slaughtering
5. Processing
6. Distribution

B. Facilitating Services

1. Assembly and distribution (transportation)
2. Pricing arrangements
3. Hedging (risk bearing)
4. Sorting and grading
5. Marketing information
 - a. feeder pig market
 - b. live hog market
 - c. wholesale primal market
 - d. retail pork cuts movement
6. Storage

C. Service and Supply Inputs

1. Financing-capital
2. Feed
3. Facilities and equipment
4. Health services
5. Technical information services

There are many ways in which these functions could be organized and the profit shared among the various concerned parties. One possibility is that after input purchases had been paid, each party would receive payment for the value he had added to the final product.^{8/} Another more conventional approach would be to commit quantity to the system, but price according to a price formula based on reported markets. No matter what profit-sharing plan is chosen, the result needs to be both flexible to take advantage of a coordinated approach and equitable to continue commitment from the various entities to the master plan.

A Long-Term Planning Model

Having briefly discussed some long range planning considerations in a coordinated hog-pork subsector, it is appropriate to briefly review some of the components that might reasonably appear in a formal planning model. Later discussion in our paper will show that formal short-run planning models are currently in use by some of the more innovative firms in the industry, and that intermediate term (i.e. within a year) planning models appear feasible, even for fully-coordinated organizations wishing to plan the production of pork from corn to consumer. Such models would probably require less than 4000 linear programming restraints, and as such tend to be toward the upper limit of economic computation, even with modern codes and computers. Thus, the possibility of "optimal" and formal coordination from corn to consumer is a relatively new development for the hog industry.

The present section of this bulletin is concerned to suggest some of the relevant considerations in the formulation of a long run planning model for fully coordinated organizations.

Multiple Objectives: There are very few organizations (just as there are very few people) that have a single objective. Typical objectives for a firm might well include:

1. Maximization of net worth, (and/or liquidity),
2. Minimization of probability of bankruptcy,
3. Maximization of the "size" of the business,
4. A reputation for innovativeness, and
5. Minimization of effort by the entrepreneur.

Within a one year planning horizon, there is frequently little conflict between these objectives. Maximization of after tax income will frequently be a good surrogate for each of the above objectives.

In the longer run, however, these objectives may well conflict. Multiple objectives are compatible with formal planning procedures, as has recently been discussed by Candler and Boehlje.^{40/}

Cash Flow: Perhaps the most important component of any long run formal planning model would have to be cash flow and taxation considerations. Paying ones' taxes and debts is the name of the game; and alternative investment/accounting options can have quite drastic implications for the liquidity of an organization.

It should be emphasized that any worthwhile long run formal planning procedure must take taxation into the planning calculus, and not merely treat it as a residual to be calculated ex poste. Similarly, the firms' long and short term borrowing capacity must be kept under constant review.

Investment: The crucial distinction between the long run and shorter time periods, is that in the long run the organization can invest (and disinvest). Many relevant types of investment activity will suggest themselves to the reader. Most of the investments which come to mind in the first instance tend to involve the purchase of physical facilities. There are, however, many other relevant types of investment. An effective promotional and advertizing program which achieves a permanent increase in market share should be viewed as an investment. The simple development of expertise and management skills within an organization may well be the most important form of investment that can be undertaken: "Look after your managers, and the organization will look after itself."

Aggregation: With current computers, it would certainly not be economical (and possibly not even possible) to plan for the sale of individual pork products by the month. Some form of aggregation would be essential.

One type of scheme which has some appeal would be to model the next year by month and individual product; but to follow this with two (or three) years modeled by quarters, and total requirements of the major primals; and possibly to follow this with a couple of years planned annually.

The point is, the further we plan into the future, the less relevant it is to have a very detailed plan. Detail is sure to be overtaken by events.

Integerization: It is characteristic of investment (which is characteristic of long term planning) that many options need to be integerized. Many investments are a "go-no go" proposition. The value of a third of a hog house (i.e. a physically incomplete hog house) is not equal to a third of the value of a hog house.

Hog housing, cool store capacity, slaughter plants, etc., are examples of investment opportunities which are valueless unless completed.

The need to obtain an integer plan for long run planning is much greater than for intermediate term planning. In the intermediate term most of the control variables are approximately continuous. This is not so for longer term planning. This suggests that when long run planning models are developed they are unlikely to have the strong linear programming orientation of planning tools currently available to the industry.

INTERMEDIATE TERM

A long run strategy for coordination would only be useful on the assumption that control could be maintained in the intermediate and short terms. A suitable intermediate term planning model is outlined in the following discussion of a prototype linear program.

A linear programming model is used as the framework because the dynamics of supply and demand relationships in the hog-pork subsector create substantial variability in the optional resource input-product output pattern. The basic orientation of the model is one of delineating optimal raw materials input and transfers under given technological and economic conditions. Four main areas are described: procurement of feeder pigs and feed ingredients; production of finished hogs with alternative feeding programs, housing systems and market weights; slaughter and processing of primal cuts; and distribution of products

to alternative retail markets.

The intermediate planning period is defined as one year. It is difficult to create a retail pork product, particularly one which is cured or smoked, in less than one year. The breeding, gestation, farrowing, finishing, processing and distribution of fresh pork generally requires from ten to fourteen months. Thus, one year appears to be an appropriate planning horizon for the intermediate term.

The annual planning horizon is subdivided by months. It could have been divided by quarters or weeks. A month was chosen because it added substantially to detail without making the model overly complex. Also, a month appeared to be a planning period which would be meaningful to decision making in both the processing and the production areas. The slaughter fabrication decisions tend to be made weekly, while mating decisions can only be implemented in something over a three week period, in any case, a fifty-two week model would be prohibitively expensive in terms of computer time.

PROTOTYPE MODEL

The prototype model developed using linear programming describes the key variables of the pork conversion process and the relationships among them (Figure 1).

The biggest technical problems faced in constructing this prototype centered on the efficient generation of the linear programming matrix from the raw data. The OPTIMA matrix generator was surprisingly slow for the structure needed in this model. A specialized matrix generator program was written in Fortran IV which permitted the matrix to be generated efficiently.

The largest conceptual difficulty was abstracting from the weekly description of the problem which was already available. It is still not clear what is likely to be the optimum degree of aggregation. This is why the following paragraph is particularly important.

It must be emphasized, at the outset, that the degree of abstraction used in this model prevents it from providing any meaningful empirical results. Rather the model illustrates the data required for coordination

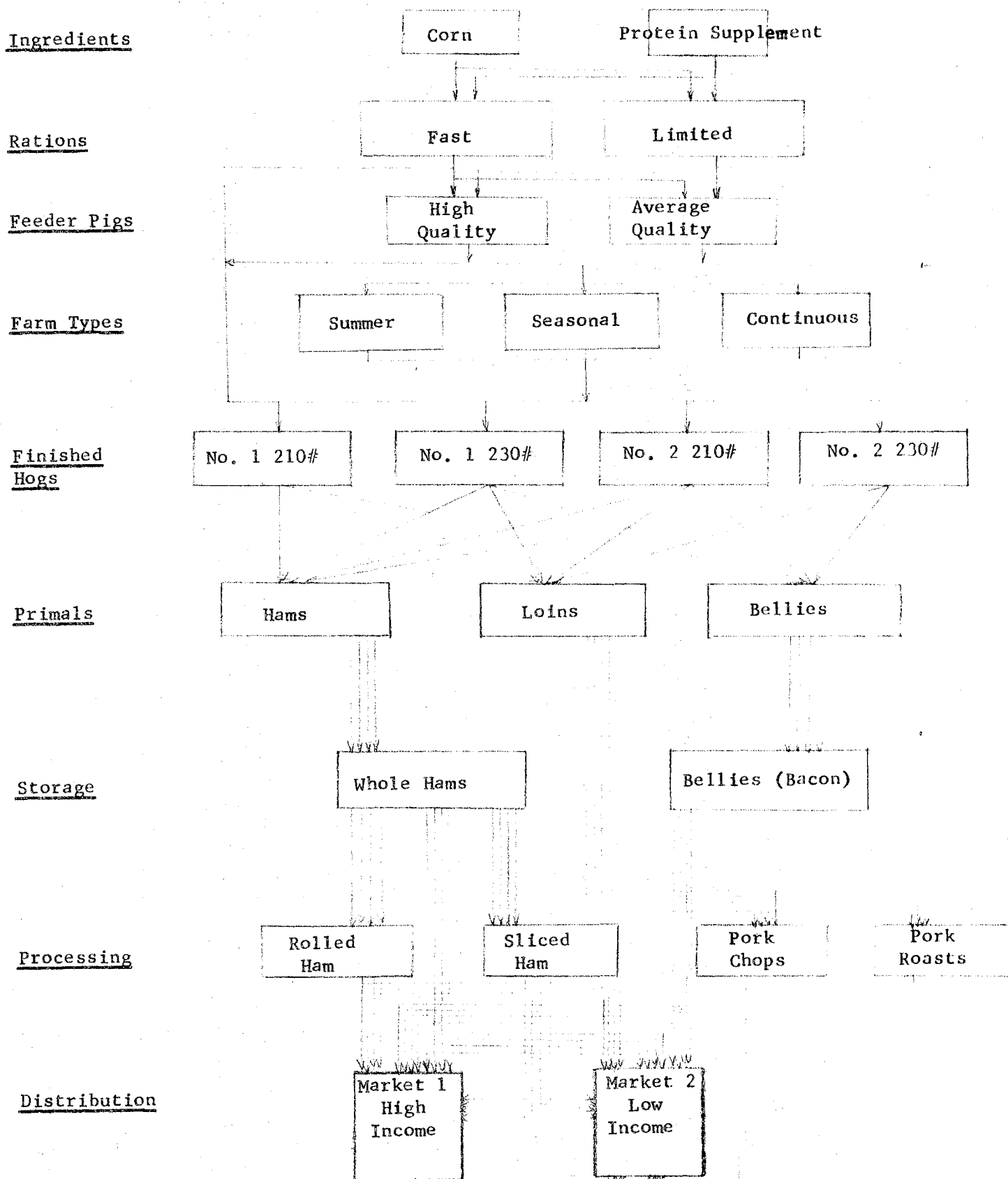


Figure 1: Schematic Representation of Production Flows in a Coordinated Hog-Pork Enterprise. (Abstracting from time)

of the industry by contract or ownership; it illustrates the types of information which would result from the use of a linear programming control model; and, it illustrates the size of the computational problems likely to be incurred in any attempts at constructing an operational intermediate term planning model.

Sophisticated models of production decisions for segments of the industry such as farrowing and finishing ^{41/} and slaughter and fabrication ^{42/} are available at either a research or operating control level. It is thought, however, that this is the first development of an explicit model of the main features of the hog-pork industry. No great originality is claimed, however, since many of the people we have talked with in developing this model were well able to visualize the types of relationships which would need to be incorporated. Indeed, it is exactly the fact that many people are now able to visualize a full industry control model that makes the current exploratory study timely.

The model allows for twelve months, with variations in the total level and patterns of demand for pork products, between months. Allowance is made for hams to be carried forward in inventory for one month, and bacon for two months. A "circular" or "steady state" model is used in that the closing inventory for each month is the opening inventory for the next month. There is no starting or ending point, February follows January ... December follows November, and January follows December.

The aim is to minimize the cost of meeting assumed fixed demands for pork products: Given these demands, what is the least cost of satisfying them? The model yields information on the quantities of feeds, feeder pigs, purchasable primal cuts, farm capacities, and the like, which should be used to minimize the cost of meeting the fixed demands. The model also yields information on the costs of various products demanded, and the value of additional farm or processing capacity.

Activities and Restraints Used

This section describes the activities (alternative) and restraints (restrictions) considered in the model. The input/output coefficients connecting these activities, and hence discussion of the detailed structure of

the model is relegated to the appendix. A full list of activities and restraints is given in Appendix A.

The model provides for the following 94 activities in each month:

1. Ingredient purchase (2 activities): Two commodities, corn and protein supplement, can be purchased in each month. In the model, it was assumed that the cost of corn and protein supplement corresponded to market price at the time the hogs were put on feed. This would correspond to a contract being written for finishing feeder pigs, with respect to the price of feed at the time of purchasing feeder pigs. Other accounting procedures could have been used. It will be recalled that this model is for a fully coordinated "corn to consumer" operation. If some hogs were being produced, say under contract, on corn-hog farms, this "purchase" of corn would reflect the accounting transfer of corn from the rest of the farm to the hog enterprise.

2. Feeder Pig Purchase (2 activities): Two qualities of feeder pigs, high quality and average quality, were assumed to be available in each month.

Quality was defined in two dimensions -- feed conversion and percentage of No. 1 carcasses. These two grades of quality might be taken to represent in some manner the difference between purchased feeder pigs and feeder pigs produced "within" the coordinating organization.

3. Hog Finishing (24 activities): Twenty-four methods of producing finished hogs were allowed in each month. These twenty-four alternatives were made up as follows:

- a) Three Farming Systems, which used either summer production, seasonal production, or continuous production,
- b) Two Qualities of Feeder Pig,
- c) Two Final Weights, 210 and 230 pounds, and
- d) Two Rates of Feeding, three and four months to maturity; and hence different rates of gain and feed efficiency.

These activities contain many important trade-offs such as the cost of gain vs. rate of gain, the weight of a carcass vs. the quality of a carcass, and the purchase price of a feeder pig vs. the demand for a quality carcass. Although literature does not agree on the magnitude of these trade-offs, certainly the variables of carcass quality, feed conversion, feeder pig quality and market weight are interconnected. Although we believe we have used some of the best available estimates of these trade-offs in our model, the data used does not claim to be anything other than illustrative of the kind of structure which would need to be developed empirically.

4. Hog Slaughter (4 activities): Provision was made for slaughter of two qualities of hog, 1's and 2's and others at two weights, 210 and 230 pounds.

The number of weight-grades could be expanded to thirty or more. But here we have used only two grades and two weights to illustrate that the number of pounds of primal cuts from each weight-grade differs. This difference is important. The heavier hogs yield more pounds, but possess a lower percentage of quality primals. This trade-off between yield and quality is a key factor in the analysis of the entire process.

5. Primal Storage (8 activities): Two of the three primals modeled can be stored. Four weight-grades of cured ham can be stored one month, and two qualities of bacon can be stored for either one month or two months. Loins are assumed to be transferred fresh to retail and therefore provision was not made in the model for the storage of loins.

6. Processing (18 activities): Hams are processed into three products: rolled hams, sliced lean ham and sliced regular ham. Loins are processed into large and regular roasts and chops. Many different assumptions could be inserted into the model at this point. This is mainly because there is little, if any, grading of pork products in the industry.

Grading, at least within the coordinated system, is vital to an approach which attempts to coordinate the effective demands of discriminating consumers with production and processing policies. In this model, quality in hams is defined as those hams taken from high quality feeder pigs, whether these hogs were slaughtered at 210 or 230 pounds. In the case of chops and roasts, quality is defined as those products sliced from large loins (thus, yielding a large loin-eye), whether these hogs were high quality or average quality feeder pigs. This is a gross abstraction, but one which could be refined with better data. The quality aspect of pork production is generally recognized to be a critical area where more research is needed.

7. Distribution: The ten pork products generated are distributed to a high income and low income market. The demand for the various pork products varies by market. Other market segmentations could have been included, but segmentation by income was sufficient to illustrate a market orientation.

Annual Activities (Five Activities Once a Year)

In addition to the above monthly activities, the model allowed for five annual activities, corresponding to purchase of additional capacity for:

1. Each Farming System (3 activities),
2. Hog Slaughter (1 activity), and
3. Cold Storage Capacity (1 activity).

These activities represent the costs of fixed buildings and equipment. The amount of capacity purchased is dictated by the amount required in the month of heaviest utilization. In other months there may be idle capacity.

Monthly Restraints (65 Restraints in Each Month)

A total of 65 restraints appeared in each month. The restraints used were:

1. Feed Balance (2 restraints): These restraints ensured that total protein and energy used in the feed rations did not exceed the total purchased through the ingredient activities.
2. Feeder Pig Balance (2 restraints): These restraints balanced the number of feeder pigs purchased against the number of market hogs produced plus mortality.
3. Hog Finishing Quality (4 restraints): These restraints transfer finished hogs into slaughter activities while keeping four weight-grade classes separate.
4. Ham Primal Cut-Out (4 restraints): These restraints sum four weight-grades of ham primals and transfer them from the slaughter activities into processing and storage activities.
5. Ham Transfer and Storage (8 restraints): These restraints subtract from current availability any hams moving into next month's storage as well as those hams transferred to processing.
6. Loin Primal Cut-Out (4 restraints): These restraints sum four weight-grades of loin primals and transfer them from slaughter activities to retail processing activities.
7. Bacon Primal Cut-Out (2 restraints): These restraints sum two grades of bacon and transfer them to transfer and storage activities.

8. Bacon Transfer and Storage (6 restraints): These restraints subtract from current availability bacon moving into storage (either one or two months) as well as current retail distribution.

9. Whole and Rolled Ham Transfer (2 restraints): These restraints balance the retail distribution of whole and rolled hams.

10. Retail Utilization (20 restraints): These restraints insure that for every pound of pork product distributed, a pound of that product has been made available for distribution.

11. Production Capacity (5 restraints): These restraints assure that adequate farm production capacity, slaughter capacity and storage capacity are available for the months in which it is needed.

Prototype Model Results

The following results were obtained from the matrix of activities and restraints described in the previous section. The exact linear programming matrix structure and coefficients used are described in appendix A. A word of caution is appropriate before discussing this "solution". The sole purpose of this discussion is to demonstrate the types of information which are available from a linear programming model applied to an intermediate term pork production planning system.

In discussing the results from the model it is important to remember that only a few representative activities were included. For instance, in any one month only four different categories of finished hogs were available for slaughter instead of the twenty-four categories with which a grade and yield scheme normally deals. In the same way only three of the five actual primal cuts are represented in this model. This leads to results which need to be interpreted with care. For instance, since only three primal cuts appear in the model, the total cost of producing the five primal cuts gets attributed to the three cuts which actually appear. The results reported are suggestive, rather than capable of literal interpretation.

The "Solution"

The overall question the linear programming model was designed to answer was: Given that retailers plan to sell (and consumers are assumed to demand) a specified number of pounds of pork chops (large and regular), pork roasts (large and regular), bacon (lean and regular), rolled hams and whole hams in two markets in each of twelve months, how could one produce these retail pork products at least cost and, at the same time, not violate any of the 240 demand constraints (12 months x 20 products x 2 markets)?

The optimal plan generated by the linear programming model reports, on a monthly basis, the flow of the conversion process from "corn to consumer". The results for the month of January (the 1st month) are presented in Table 2 and illustrate the information available.

Beginning with ingredient purchase, 4,763 cwt. of corn and 813 cwt. of protein supplement were purchased at \$1.94 and \$5.00 per cwt., respectively, together with 1011 head of average quality feeder pigs at \$10.00 per head.

At the same time the plan calls for 533 head of fast-fed (three month) market hogs to be slaughtered, resulting in 896 cwt. of No. 1 quality and 224 cwt. of No. 2 quality lightweight carcasses. (These hogs were put on feed in October, and produced using the high capital intensive-year round finishing system.)

From these 533 carcasses, 9,612 pounds of lean bacon and 1,674 pounds of regular bacon were packaged for consumption in the month of January, and 407 pounds and 365 pounds of regular bacon were packaged for storage into the months of February and March, respectively.

Outside purchases of hams were significant -- 3,617 pounds of high quality 12/14 pound hams and 660 pounds of low quality 12/14 pound hams were purchased at \$.50 per pound.

Hams from slaughter totaled 19,337 pounds: made up of 11,253 pounds of 10/12 pound quality hams; 2,956 pounds of 12/14 pound average hams, and 5,128 pounds of 12/14 pound quality hams.

A total of 244 pounds of ham were put into storage and a total of 694 pounds were withdrawn. In both cases, 12/14 pound low quality were involved. None of this type of ham was generated from slaughter.

Table 2. Activities in the Optimal Plan for January

Code	Description	Produced	Cost/Unit
1	Corn Purchased (cwt.)	4763.	1.94
2	Protein Supp. (cwt.)	813.	5.00
4	Ave. Feeder Pigs (head)	1011.	10.00
27	Average 3 month 210# Finished Hog Totally Slotted System (head)	533.	3.50
29	Lt. Wt. No. 1 Car. (cwt.)	896.	0.
30	Lt. Wt. No. 2 Car. (cwt.)	224.	0.
33	Lean Bacon to Ret. (lbs.)	9612.	0.
34	Reg. Bacon to Ret. (lbs.)	1674.	0.
36	Reg. Bacon to Feb. Storage (lbs.)	407.	0.
38	Reg. Bacon to Mar. Storage (lbs.)	365.	0.
41	12/14 Qu. Ham Pur. (lbs.)	3617.	.50
42	12/14 Av. Ham Pur. (lbs.)	660.	.50
43	10/12 Qu. Ham Cut-out (lbs.)	11253.	0.
44	10/12 Av. Ham Cut-out (lbs.)	2956.	0.
45	12/14 Qu. Ham Cut-out (lbs.)	5128.	0.
50	12/14 Qu. Ham to Feb. Storage	244.	0.
54	12/14 Qu. Ham from Dec. Storage	694.	0.
56	Av. Whole Hams to Retail (lbs.)	557.	0.
60	Rolled Hams to Retail (lbs.)	682.	0.
63	Ln. Sl. Ham to Retail (lbs.)	11253.	0.
64	Rg. Sl. Ham to Retail (lbs.)	1035.	0.
65	Ln. Sl. Ham to Retail (lbs.)	8746.	0.
66	Rg. Sl. Ham to Retail (lbs.)	1355.	0.
68	Rg. Loin to Retail (lbs.)	11190.	0.
69	Lg. Loin to Retail (lbs.)	3151.	0.
70	Lg. Loin to Retail (lbs.)	2806.	0.
72	Reg. Bacon from Nov. Storage	264.	0.

A total of 557 pounds of whole hams, 682 pounds of rolled hams, and 22,289 pounds of sliced ham was transferred to the retail section of the model. The sliced ham component was made up of 19,999 pounds of lean cuts and 2390 pounds of regular cuts. (These figures are obtained from Table 2 by adding code lines number 63 and 65, and 64 and 66, respectively.)

A total of 17,147 pounds of loin was transferred to the retail section of the model. This was comprised of 5,957 pounds of large loins and 11,190 pounds of regular loins.

The retail demand for 264 pounds of regular bacon was met using bacon which was placed into storage during the previous November.

The above plan meets all retail demand requirements at least cost, not only for January but for an entire twelve month planning period.

In addition to telling us what activities to use, the optimal plan tells us what activities not to use. A sample of these activities for the month of January has been reported in Table 3. The third column of Table 3 gives the actual cost per unit used in our plan, and the final column gives a penalty cost (or shadow price) per unit, for including the activity. The significance of these penalty costs can be seen from the following examples.

Feeder pigs -- high quality feeder pigs were not in the optimal plan for January. The penalty cost of including them in the solution is \$4.30 per head. Thus, these pigs would have been competitive only if priced at \$8.70, or \$1.30 less than the original \$10.00 price. Using penalty costs in this manner, one can develop a precise value of worth of feeder pigs of various grades. This type of information could be useful in decisions concerning the purchase of feeder pigs and/or the negotiation of feeder pig contracts.

Housing Systems -- Conventional and partially slotted housing systems were not part of the January optimal plan because an artificial price (\$100) was arbitrarily assigned to these activities for that purpose. These activities were blocked out of solution intentionally in order to represent the seasonal availability of the three housing systems. It is assumed in this example that conventional and partial slotted housing is unavailable during January and, thus, all production occurs in the fully slotted housing activities. The partially slotted house is unavailable since the technology modelled is an open partially slotted house. If it were technically possible to produce 230 pound finished hogs, using the conventional system, for slaughter in January, we could afford to pay up to \$4.33 per head ($4.33 = 100 - 96.97$) to use the technology.

Table 3. A Sample of Activities Not in the Optimal Plan for January

Code	Description	Cost/Unit	Penalty Cost/Unit
3	High Quality Feeder Pigs (head)	13.00	4.30
5	Quality 4 month 210# Finished Hog Conventional System (head)	100.00	95.69
6	Quality 4 month 230# Finished Hog Conventional System (head)	100.00	96.97
7	Average 4 month 210# Finished Hog Conventional System (head)	100.00	96.91
8	Average 4 month 230# Finished Hog Conventional System (head)	100.00	95.48
9	Quality 4 month 210# Finished Hog Partially Slotted System (head)	100.00	97.73
10	Quality 4 month 230# Finished Hog Partially Slotted System (head)	100.00	99.00
13	Quality 4 month 210# Finished Hog Totally Slotted System (head)	4.17	1.51
14	Quality 4 month 230# Finished Hog Totally Slotted System (head)	4.17	2.79
25	Quality 3 month 210# Finished Hog Totally Slotted System	3.50	1.27
26	Quality 3 month 230# Finished Hog Totally Slotted System	3.50	1.57
32	Hv. Wt. No. 2 Carcass (cwt.)	0.	4.04
37	Lean Bacon to February Storage (lbs.)	0.	0.
49	10/12 Av. Ham to Feb. Storage (lbs.)	0.	0.

Feeding Programs -- The four month feeding program in the fully slotted housing activities was not used in the optimal plan for January. The penalty cost of producing a quality four month 210 pound finished hog in a totally slotted system is \$1.51 per head. That is, the additional cost of a four month feeding program compared to a three month feeding program is \$1.51 per head. In this case, the penalty cost aids in assessing the economic consequences of alternative feeding programs.

Market Weight -- No hogs were fed to the heavier weight (230 pounds) in the optimal plan for January. The penalty cost for each hundred pounds of heavy carcass transferred is \$4.04. This means that a rather severe loss of \$9.29 would be incurred for each 230 pound hog transferred.

Storage -- Lean bacon and 10/12 pound hams were not stored in February. However, there is no penalty cost for such storage. This means that, cost-wise, there is no difference if lean bacon and 10/12 hams are stored or not.

This basic information can, of course, be rearranged in other ways. It might, for instance, be convenient for the hog production manager to have a break down, as in Table 4, of hogs to be placed on feed, and planned ingredient purchases. It is rather suggestive to note that even for a "least cost" prototype fully coordinated hog production system, there are very substantial savings in number of hogs placed on feed going from a low of 238 in May, to a high of 502 in September.

The slaughter plant manager might wish to know the anticipated slaughter pattern for the year. An appropriate summary is provided in Table 5. It is interesting to note that the "least cost" fluctuations in hogs slaughtered is substantially smaller than the savings in hogs placed on feed.

Similarly the anticipated cash expenses might be of interest. This is presented in Table 6. Taken together with the average monthly cost of planned increases in capacity, the total cost minimized by the plan is \$191,680. Any other plan which met the retail sales constraints would have higher total costs.

Similarly, the penalty cost of including particular activities in the plan can be tabulated in a way which would be useful to management. A selected example of this type of information is provided in Table 7. It is interesting to note that when a systems approach is taken to the annual production plan, several "intuitively obvious" relationships fail to hold. Though in the

Table 4. Hogs Placed on Feed and Ingredients Purchased, by Months

<u>Month</u>	<u>Hogs Placed on Feed</u> (Head)	<u>Corn Purchases</u> (cwt.)	<u>Soybean Purchases</u> (cwt.)
Jan	533	4763	813
Feb	466	1966	291
Mar	433	1339	166
Apr	291	650	62
May	238	497	87
June	436	2177	383
July	438	4255	724
Aug	458	2261	370
Sept	502	1970	310
Oct	435	1253	155
Nov	272	1176	146
Dec	255	0	0
Total	<u>4757</u>	<u>22307</u>	<u>3507</u>

Table 5. Planned Hog Slaughter (in Head), by Months

<u>Month</u>	<u>3 Month Program</u>		<u>4 Month Program</u>		<u>Total</u>
	220 lbs.	240 lbs.	220 lbs.	240 lbs.	
Jan	533				533
Feb			466		466
Mar			355	98	433
Apr			121	170	291
May	99			139	238
June	436				436
July	438				438
Aug			458		458
Sept	502				502
Oct			394	41	435
Nov			113	159	272
Dec			106	149	255
Total	<u>2008</u>	<u>0</u>	<u>1993</u>	<u>756</u>	<u>4757</u>

Table 6. Cash Expense Analysis for Planned Production

Month	Pigs	Feed	Cash Outflow		Conv.	Partial Slots	Total Slots	Slaughter	Freezer	TOTAL
			Production	Hams						
Jan.	\$10110	13305	1865	2108						
Feb.	5232	5288	1943	1946						
Mar.	4102	3467	1805	6176						
Apr.	2240	1574	1213	8685						
May	1414	1409	929	7136						
June	4862	6183	1526	2205						
July	8172	12152	5548	2154						
Aug.	5566	6409	1905	1553						
Sept.	5707	5623	2093	2309						
Oct.	3850	3160	1813	4144						
Nov.	3870	2917	1134	8123						
Dec.	0	0	0	8472						
Annual					0	0	1951	56	9.58	
TOTAL	55125	61487	21774	49533	0	0	1951	56	9.58	<u>\$191,680</u>

Table 7. Cost of Including Non-Solution Activities in Solution*

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
3	Quality Feeder Pigs	4.30	3.72	2.69	3.68	4.31	5.88	4.89	4.32	2.67	0.	2.76	3.86
16	4 mo. Feeding Prog.	2.74	-	-	-	-	-	0.	-	-	-	-	-
27	3 mo. Feeding Prog.	-	3.13	3.20	1.44	1.00	1.94	-	3.17	2.88	1.30	1.84	0.
19	Conventional Hous.	-6.00	-3.00	-3.00	-3.00	-4.00	-5.00	.29	3.44	-1.00	-3.00	-2.00	-4.00
23	Partial Slotted Hous.	-2.00	-2.00	-2.00	-3.00	.54	.02	.0	3.18	3.40	1.84	100.00	-2.00
25	210# No. 1	1.27	3.36	4.27	1.49	.55	.66	1.31	3.82	3.58	5.11	2.86	.0
26	230# No. 1	1.57	5.78	4.76	1.90	.0	.0	1.15	7.18	5.40	5.60	3.32	.35

* Negative entries in this table correspond to technologically impossible changes. The negative, interpreted as absolute amounts, give us the extra profit available if the technological barrier was to be overcome.

present case this may, of course, be more a feature of the model used, than of the real world being modeled.

As examples, consider the following:

Feeder Pigs - High quality feeder pigs were generally excluded from the solution. The penalty cost of bringing them into solution varies from month to month, but ranges from \$0.00 to \$5.88.

Feeding Program - In the first month, a three month feeding program is selected and the four month feeding program is omitted from solution. In most of the other months, the four month feeding program is selected and the three month program is omitted.

The cost of using the four month feeding program in the first month is \$2.74. The cost of using the three month program in the other months ranges from \$1.30 to \$3.20.

Housing Systems - The continuous production system was chosen in all seasons, in preference to summer or seasonal production. In May, June, July and August, however, the seasonal production system could have been included in the solution for a cost of .54, .02, .29 and 3.44 dollars per hog, respectively.

Market Weight - Primary emphasis in the solution was on the lighter (210#) hog. To bring the heavier (230#) hog into solution would add a cost of from \$.30 to \$4.64 per head.

The Value of Restraints

A linear programming model provides economic information in several dimensions other than the level of activities in solution and the opportunity cost of including excluded activities.

Economic information is generated on the restraints which are modeled. If a restraint is effective in the solution, then it has a "shadow price". If a restraint is not effective in the solution, then it has a "slack", or amount of the resource not used.

The shadow prices in the optimal plan for January are listed in Table 8A. These prices indicate the change in cost to the entire solution which would result from a one unit change in restraint. For example, in the first line of Table 8A, the shadow price on the protein balance restraint is .09. This means that an additional unit (pound) of protein, if required, would add nine cents to the total cost of the plan. Similarly, the shadow price

Table 8A. Optimum Plan for January: Shadow Prices

Code	Description	Shadow Price
1	Protein Balance (lbs.)	.09
2	Energy Balance (10 lbs.)	.29
3	High Quality Feeder Pig Transfer (head)	0.00
4	Av, Quality Feeder Pig Transfer (head)	8.69
5	High Quality Light Carcass Transfer	3.16
6	Low Quality Light Carcass Transfer	3.84
7	Average Quality Light Carcass Transfer	9.15
8	Average Quality Heavy Carcass Transfer	3.84
9	10/12 lb. Quality Ham Cutout	.50
10	10/12 lb. Average Ham Cutout	.50
11	12/14 lb. Quality Ham Cutout	.50
12	12/14 lb. Average Ham Cutout	.50
13	10/12 lb. Quality Ham Processing	.50
14	10/12 lb. Average Ham Processing	.50
15	12/14 lb. Quality Ham Processing	.50
16	10/12 lb. Average Ham Processing	.50
17	10/12 lb. Quality Ham Purchase	.50
18	10/12 lb. Average Ham Purchase	.50
19	12/14 lb. Quality Ham Purchase	.50
20	12/14 lb. Average Ham Purchase	.50
21	8/12 lb. Quality Loin Transfer	0.
22	8/12 lb. Average Loin Transfer	.60
23	12/16 lb. Quality Loin Transfer	.60
24	12/16 lb. Average Loin Transfer	.0
25	Lean Center Ham Slices - Processing	4.54
26	Regular Center Ham Slices - Processing	4.54
27	Regular Pork Chops - Retail Processing	0.
28	Large Pork Chops - Retail Processing	2.52
29	Regular Pork Roasts - Retail Processing	0.
30	Large Pork Roast - Retail Processing	0.
31	Lean Bacon Transfer	0.
32	Regular Bacon Transfer	.91
33	Lean Bacon - Retail Processing	0.
34	Regular Bacon - Retail Processing	.91
35	Lean Bacon - February Storage	0.
36	Regular Bacon - February Storage	.91
37	Lean Bacon - March Storage	0.
38	Regular Bacon - March Storage	.91
39	Whole Hams - Retail Transfer	.50
40	Rolled Hams - Retail Transfer	1.00
41	Lean Ham Center Slices	4.54
42	Regular Ham Center Slices	4.54
43	Regular Pork Chops	0.
44	Large Pork Chops	2.89
45	Regular Pork Roasts	0.
46	Large Pork Roasts	0.
47	Lean Bacon	0.
48	Regular Bacon	.91
49	Whole Hams	.50
50	Rolled Hams	1.00
61	Housing Capacity - Conventional System	0.
62	Housing Capacity - Partially Slotted System	0.
63	Housing Capacity - Fully Slotted System	1.58
64	Slaughtering Capacity	.005
65	Freezer Capacity	0.

on the second row, the energy balance restraint, shows a figure of .29 per unit (10 pound unit) which indicates an increased cost to the solution of 2.9 cents if an additional pound of energy were required. Thus, the bulk of the feed cost, at least on a per pound basis, is for the purchase of protein, not energy.

As another example, the shadow price of feeder pigs is \$8.69. That is, if we could "out of thin air" produce an extra high quality feeder pig in January, profit would rise by \$8.69. In practice, of course, the feed and other costs to produce this extra feeder pig would be almost (probably exactly) \$8.69; and, that explains why the plan does not suggest the production of extra feeder pigs.

Looking at the shadow prices on the retail products, it is evident that in our model, ham is the really expensive item to produce. If Table 8A referred to a real plan, the sales manager should instruct his sales force to try and lose orders for hams!

The slacks in the optimal plan for January are listed in Table 8B. These slacks indicate those "restraints" which are not effective. The magnitude of each slack is given. For example, the slack on 12/16 pound average loin transfer is 320 units (pounds). This means that 320 pounds were produced in excess of requirements. In essence, 12/16 pound average loins turn out to be a byproduct of the other production requirements. The sales force could be instructed to push average loins, even if price suffered to some extent.

The shadow prices and slacks could be tabulated in a variety of ways which are likely to be useful to the management.

Table 8B. Optimal Plan for January: Slacks

Code	Description	Slack
24	12/16 lb. Average Loin Transfer (lbs.)	320.
30	Large Pork Roast - Retail Processing (lbs.)	1788.
43	Regular Pork Chops (lbs.)	1868.
46	Large Pork Roasts (lbs.)	664.
47	Lean Bacon (lbs.)	8623.

Shadow Prices

Shadow prices, by month, for a year are contained in Tables 9, 10, 11 and 12. The interpretation of these sample values is presented in four parts.

Shadow Prices on Feed Ingredients and Feeder Pig Purchase: The shadow prices on the two nutrients, protein and energy, remain relatively constant compared to the shadow price pattern on feeder pig purchases. The latter values indicate a significant seasonal change in the worth of feeder pigs to the annual solution.

Table 9 tends to confirm the argument that there are very significant economic forces behind the observed price fluctuations in the feeder pig market. It is noticeable that the premium for low priced feeder pigs, in our model, is much more constant than the actual price level, though October provides an exception to the point where high priced feeder pigs are more valuable than the lower priced ones.

Shadow Prices on Hog Weight-Grade Restraints: The shadow prices on the four weight-grades of hogs in the model are reported in Table 10, and illustrate the cost to the entire process which would result from an additional hundredweight slaughtered. For example, in January the additional cost of a one unit change in the av. quality light carcass restraint is \$23 compared to \$53 for a one unit change in the av. quality heavy carcass restraint. Similarly, the additional cost for an additional unit change in the high quality light carcass restraint is only \$19 compared to \$53 for the high quality heavy carcass restraint. These differentials hold a fairly constant relationship for the other months.

While these shadow prices suggest that high quality hogs have more influence on the total systems cost than average quality hogs and heavy hogs have more impact than light hogs, the magnitude of the relationship should only be considered illustrative. The point is that with shadow prices like these applied to a real situation, management can know specifically what each weight-grade carcass is worth in relation to the total cost structure.

Shadow Prices on Transfer, Processing, and Storage Restraints: The shadow prices on all ham cut-out, processing and purchase activities are the same -- \$.50 per pound. The \$.50 price on ham outside purchase alternatives sets this limit.

Table 9. Shadow Prices on Feed Ingredient and Feeder Pig Purchase, by Month

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	Protein Balance	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
2	Energy Balance	.02	.03	.03	.02	.03	.03	.03	.03	.03	.02	.02	.01
3	High Quality Feeder Pig Transfer	8.	10.	12.	13.	11.	9.	8.	9.	11.	15.	13.	13.
4	Low Quality Feeder Pig Transfer	10.	12.	14.	16.	14.	11.	9.	11.	13.	14.	15.	16.

Table 10. Shadow Prices on Hog Weight-Grades

Code	Description	Jan.	Feb.	Mar. (\$/cwt.)	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
5	High Qu. Light Carcass	23	22	23	23	23	23	22	21	22	23	23	24
6	High Qu. Heavy Carcass	53	51	56	58	58	53	49	46	51	56	56	57
7	Ave. Qu. Light Carcass	19	16	21	24	24	22	21	11	17	21	22	22
8	Ave. Qu. Heavy Carcass	53	52	46	47	48	44	41	56	51	46	46	47

The shadow prices on transfers, however, vary by month. These values, which range from .35 to .78 cents per pound, indicate the change in total plan cost given a one pound change in the loin transfer restraint. Such information might be beneficial as a guide in merchandising loin cuts.

Shadow Prices on Retail Product Restraints: The decrease in cost resulting from a one unit change in the demand for sliced ham amounts to \$4.54 per pound. This value can be traced to the wholesale value of ham purchased which is \$.50/pound. Since only 11% of the wholesale ham can be used as center sliced ham, the value of a pound of sliced ham is approximately nine times the value of a pound of wholesale ham. This shadow price would be different (very likely lower) in a complete model which gives credit for the butt and shank portion of the wholesale ham. The value of hams and bacon in Table 11 are dictated by the price at which primals can be bought. The model, probably unrealistically, assumed that the primal price was unchanged throughout the year.

The shadow prices on large pork chops illustrate over the twelve month period the value to the system of a one unit change in the demand for this product. The value on large pork chops ranges from a low of \$1.47 in June and August to a high of \$3.25 in March.

In contrast, the shadow prices on regular pork chops range from zero to a high of \$.27 per pound. This situation indicates that the production of large pork chops is a bottleneck whereas the production of regular pork chops is not nearly so critical.

In further contrast, the production of pork roast to meet demands is such that a one unit change in demand would not affect costs at all.

Bacon, like ham, has a very constant shadow price over all months. This is because it is a storable item. The available supply is balanced with demands after storage costs are considered, causing the shadow price to even out over the year.

Table 11. Sample of Shadow Prices on Transfer, Processing, and Storage Restraints

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
9	10/12 lb. Quality Ham Cut-out	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
13	10/12 lb. Quality Ham Processing	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
17	10/12 lb. Quality Ham Purchase	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
21	8/12 lb. Quality Loin Transfer	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.006	.03
22	8/12 lb. Average Loin Transfer	.60	.51	.69	.76	.78	.61	.45	.35	.53	.69	.70	.72
23	12/16 lb. Quality Loin Transfer	.60	.51	.69	.76	.78	.61	.45	.35	.53	.69	.70	.72
25	Lean Center Ham Slices-Processing	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54
28	Large Pork Chops-Retail Processing	2.52	2.12	2.89	3.17	3.25	2.54	1.88	1.47	2.24	2.89	2.92	3.03
32	Regular Bacon Transfer	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91
38	Regular Bacon-March Storage	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91
39	Whole Hams-Retail	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
40	Rolled Ham-Retail	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 12. Shadow Prices on Product Demand Restraints, By Month

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
41	Ln. Sl. Ham	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54
42	Rg. Sl. Ham	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.50	4.54
43	Rg. Pork Chops	0.	.27	.12	0.	0.	0.	0.	0.	0.	0.	.026	.127
44	Lg. Pork Chops	2.89	3.17	3.25	2.54	1.88	1.47	1.88	1.47	2.24	2.89	2.92	3.03
45	Rg. Pork Roast	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
46	Lg. Pork Roast	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
47	Ln. Bacon	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
48	Rg. Bacon	.91	.91	.91	.90	.90	.90	.90	.90	.90	.90	.91	.91
49	Whole Ham	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
50	Rolled Ham	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Slacks

The slacks in the solution are useful in tracing the idle or unused resources in the plan. For example, in Table 13, regular pork roasts are in surplus in every month (considering the two markets as one). On the other hand, regular pork chops are only in surplus five months of the year. This indicates that a different cutting method at retail to increase the yield of chops and decrease the yield of roasts may have considerable value.

In Table 14, the slacks on the production, processing, transfer and storage restraints are listed. Lean bacon is definitely in surplus given the requirements placed into this particular formulation. In total, 52,399 pounds of lean bacon are slack. This figure is obtained by adding rows 31, 33 and 37, all bacon restraints.

Table 15 lists the slacks on the capacity restraints. Housing is not at all full capacity in all months, except for the conventional system. The partially slotted housing system has available but unused capacity in the first six months, and the fully slotted housing system has available but unused capacity in nine months. Slaughter capacity exists in all but two months and freezer capacity exists in only two months. (The zero housing slacks relate to the artificial costs placed on the housing activities. For example, the conventional housing system shows slacks only in those six months in which an artificially high cost was placed on them. In other months, the conventional housing system is at full capacity and there are no slacks indicated.)

Summary-Prototype Model

The results which have just been discussed serve to illustrate the key linkages which exist in the process of converting corn to pork. The quality and cost of retail pork cuts is influenced by the interaction of processing, slaughtering, finishing, feeder pig feeding and housing policies.

Some policy alternatives, while increasing the quality of retail pork, cost so much as to negate the improvement in quality. Other alternatives may add to total effectiveness in some months and detract in others. All

Table 13. Slacks on Product Demand Restraints, by Month

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
High Income Market													
41	Lean Ham Center Slices												
42	Reg. Ham Center Slices												
43	Reg. Pork Chops	1868		929									
44	Large Pork Chops						1528						
45	Reg. Pork Roasts	664	1565	1023	231			1472	1538		1280	216	202
46	Large Pork Roasts		581		662		543	547			617	619	581
47	Lean Bacon	8629		6142	3210								
48	Regular Bacon												
49	Whole Hams												
50	Rolled Hams												
Low Income Market													
51	Lean Ham Center Slices												
52	Reg. Ham Center Slices												
53	Reg. Pork Chops							1538	1606	1759			
54	Large Pork Chops												
55	Reg. Pork Roasts					189							
56	Reg. Pork Roasts			712		543			571	625			
57	Lean Bacon												
58	Reg. Bacon												
59	Whole Hams												
60	Rolled Hams												

Table 14. Slacks on Production, Processing, Transfer and Storage Restraints, by Month

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Average Loin Transfer:													
24	12/16	320	280	561	698	573	262	263	275	301	390	653	613
27	Reg. Chops-Processed										1277		
29	Reg. Roast-Processed	1789	1635				1463			1684			
31	Lean Bacon Transfer						7058	7102	7420	8126	6688	3002	2818
33	Lean Bacon-Processed		7552										
37	Lean Bacon-Mar.					2633							

Table 15. Slacks on Capacity Restraints, by Month

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
61	Housing-Conv. System		0	0	0	0	0	0					
62	Housing-Partial Slots	393	761	758	689	689	689	0	0	0			
63	Housing-Full Slots	139	190	474	262			55	257	760	196	35	
64	Slaughter Capacity		175	216	590	203	198	157	65	195	515	553	
65	Freezer Capacity				349	958							

these tradeoffs form a very complex analytical problem. The prototype model discussed in this section illustrates that large-scale linear programming is one methodology which can not only describe these multiple tradeoffs, but can solve for an optimal plan.

We now turn our attention to the question of "What would be involved in the formulation of an operational, intermediate-term, planning model for a fully coordinated production system?".

OPERATIONAL MODEL

Our primary concern, in this section, is to consider how many activities and restraints would be needed in a real world intermediate term planning model.

This discussion is bound to be, to some extent, subjective, but despite this we believe an estimate to be worthwhile. The needed activities and restraints will be discussed under the same headings used in the discussion of the prototype model.

The planning horizon (annual) and planning periods (monthly) are the same for the pro-forma operational model and the prototype model. The additional activities and restraints do not change the basic structure of the model but simply add more detail to the skeletal model structure described above.

Monthly Activities

1. Ingredient Purchase: The feed use and purchase activities for any month should probably include at least use of available corn, purchase of additional corn, purchase of soybean meal for farm formulation, purchase of pre-mix and purchase of a fully formulated feed. The actual composition and cost of fully formulated feeds could be programmed separately, and the results be included as the activities each month in the main model. This would give five feed purchase activities, plus corn and soybean inventory activities, for a total of seven activities.

2. Feeder Pig Procurement: In a properly formulated hog-pork industry analysis feeder pig procurement activities would include both "make" and

"buy" alternatives. In the above model, we have abstracted from the feeder pig production set of alternatives. However, in a fully coordinated system, hog breeding and farrowing would be included. Ideally, there would be several choices among blood lines which could be multiplied and transferred to the finishing function. Practically speaking, in the short run at least, the choice would likely be among alternative feeder pig production units. Each unit might have a different genetic makeup but the major coordination problem would center on the productivity of each unit. A unit which has a disease problem or a conception problem, for example, may be considerably lower in production than other units. Scheduling breeding programs to balance with finishing and slaughter schedules would be a problem which should be included in the model. Three types of farrowing systems might be adequate.

In addition, several activities representing feeder pig purchase alternatives should be included. These activities might represent purchases from local independent feeder pig producers as well as out-of-state feeder pig sources. Including the two purchase activities, we would have five feeder pig production activities in each unit.

Hence, at least five activities would be required to model the farrowing function, from gestation through the nursery stage, excluding the breeding policy question. Assuming three types of farrowing units, the basic activities would have to include housing capacities for gestation, farrowing, and nursery functions on the three types of farms.

3. Gilt Replacement: These would be new activities designed to insure adequate breeding stock availability on the assumption that sows were identified by farrowing systems. Allowing for acquisition, retention, breeding and sale would require 4 activities for each farrowing system or a total of 12 extra activities.

4. Hog Finishing: In an operational model, it might be reasonable to add a fourth finishing system. The number of weight-grade classifications would also increase, from 4 in the prototype, to as many as 24. With the same feeding program as exists in the prototype model the number of activities would expand from 24 to 96.

5. Hog Slaughter: Estimates in this area are more valid since operating

models are available and are being used. These models contain at least 24 weight-grade categories of butcher hogs and an additional 24 categories for sows. Provision has already been made above for disposal of breeding stock. Since the prototype models only 4 weight-grade groups, this is a 12-fold increase in the number of activities.

6. Primal Purchase: Again, operational models can guide our estimates of what is required with regard to primal purchase. There is a wholesale market for every major primal cut. In the prototype, only 3 of the 5 primals are modeled and of those, only ham was purchased at wholesale. Therefore, in an operational model, loins, bellies, picnics and Boston butts would be included in the wholesale purchase activities. The expansion of activities in this section would be considerable depending on the number of weight categories chosen. A good guide is the National Provisioner Daily Market Service, the so-called "yellow sheet", which lists wholesale prices on major primal classifications. This sheet lists 4 weights of bellies, 4 weights of loins, 3 Boston butts, 3 picnics and 6 hams. The yellow sheet is, however, only a guide. Quality differentials are not well reflected in the yellow sheet, and in practice, in an operational model, the firm would have to enter purchase and sale prices corresponding to the opportunities actually open to it.

If all these wholesale purchase options were included in an operational model, this would be an increase of 16 over the 4 included in the prototype, which would bring the total to 20.

7. Primal Storage and Transfer: With regard to storage activities, operational models again provide guidelines to estimate the number of activities. Although these models have a weekly planning horizon, storage is represented by inter-company transfer activities. The number of these activities, 40, is over five times the 8 storage activities included in prototype. Transfer activities would multiply in a similar ratio to 67, creating a total number of 107 storage and transfer activities.

8. Processing: Short term operational models for wholesale primal cut processing contain at least 130 activities. For example, in operational models wholesale ham processing (converting green hams to various styles of boned and rolled hams) requires 100 activities. Thus, the 8 activities used in the prototype model are but a sample of the total needed for this function. A reasonable aggregation of wholesale processing activities would be 48 activities.

With regard to retail processing, the prototype contains a sample of

cutout activities for hams and loins; namely, center cut ham slices and pork chops and roasts. This section would need to be expanded to include all parts of the ham and loin in addition to the alternative retail cuts for the Boston butt, the picnic and the bellies. The National Livestock and Meat Board suggest that the major retail cuts of pork are: ham (7), loin (13), picnic (6), Boston butt (4), belly (8). Thus, at a minimum, the activities would need to increase from the present modeling of 3 products to a modeling of up to 38 retail processed products. The number of activities can only be estimated since there is no operational model in this area. However, it is safe to assume that over 10 times as many activities will be required as the model is expanded from 3 to 38 retail processed products.

In total, the number of processing activities (wholesale and retail) in the prototype number 16. If an operational model of wholesale processing contains 48 and a performance model of retail processing contains 38, then the total number of 86 would be an increase of 32 over the prototype.

9. Distribution: Retail distribution of ten products to two stores was represented in the present model. A recent meat industry report ^{43/} codes 38 pork products in their "meat system". Within any one of these pork products there may be many package sizes and labellings. It is reasonable to aggregate across package size, label and final store assignment. The important point is to produce the total mix of retail products at least cost. Once produced, the allocation to package, label and store can be made without interaction with the rest of the system.

10. Annual Activities: The operational model would involve the derivation of an annual plan, subject to fixed building and facility availabilities. This means that the purchase of additional capacity, within any one year is unlikely to be a realistic alternative and the capacity activities can be removed. Rather, actual capacities will appear as restraints in each month and the derived plan would have to conform with these capacities.

11. Total Activities: The estimated number of total model activities is 5,028 for an operational intermediate term model. (Table 15) Thus, a

Table 15. Estimated Activities for Operational Intermediate-Term Planning Model

Function	Model	
	Prototype	Operational
Ingredient Purchase	2	7
Feeder Pig Procurement	2	5
Gilt Replacement	0	12
Hog Finishing	24	96
Hog Slaughter	4	48
Primal Purchase	4	20
Primal Storage and Transfer	18	107
Processing	16	86
Distribution	20	38
Monthly	94	419
Finishing Capacity	3	0
Slaughter Capacity	1	0
Storage Capacity	1	0
Yearly	5	0 *
Total Activities	1,133	5,028

* See paragraph 10.

less than five-fold increase in the size of the prototype would be required to construct an operational annual planning model. It is important to note that this enlarged model would still abstract greatly from short-run decision-making. This means it should be used only in conjunction with a short-term planning model.

Monthly Restraints

The monthly restraints, except for the retail pork product demands, are balancing equations. These equations permit the transfer of various quantities of ingredients, hogs, carcasses, primals and retail pork products from one process to another and insure that more quantity is not transferred than is produced in the previous function. Since it would be somewhat repetitious to list here all of the additional balancing equations that would be required in an enlarged model, this listing has been relegated to Appendix B. Table 16 indicates the total estimated number of restraints, by function.

Table 16. Estimated Restraints for Operational Intermediate-Term Planning Model

Function	Model	
	Prototype	Operational
Ingredient Purchase	2	2
Feeder Pig Procurement	2	4
Gilt Replacement	0	3
Hog Finishing	4	48
Hog Slaughter	10	72
Primal Purchase	4	20
Primal Storage	8	40
Processing	10	38
Distribution	20	38
Capacities	5	0
Monthly	65	365
Total Restraints	780	4380

Discussion

The above section has shown that an intermediate-term linear programming planning model for a fully coordinated hog-pork firm, based on twelve monthly time intervals, would fall within the capacity of modern computers. As formulated with 4380, this model would border on the upper edge of efficient computing capacity for all but the largest of the modern computers. This estimate is, however, something of an upper bound. As any particular firm came to be modeled, economics of problem definition would almost certainly present themselves as, for instance, in the use of bounded variables.

SHORT RUN

The "short run" is used in the following discussion to refer to a period of one or two days to one or two weeks. A short run model, by definition, may be taken to include information pertaining to, at most, three weeks into the future.

With this definition, many apparently short run problems such as: Which feeder pigs to buy this week? How many sows to **breed**? And, should I operate on the pork bellies futures market today? are seen to be intermediate run problems, since they can only be answered optimally by using information, or expectations, with respect to prices and demands in future months.

Again, because of the restricted definition of short run used in this bulletin, the major short run management decisions in the hog-pork industry relate to feed procurement and mixing and hog slaughter and pork fabrication: the activities of feed and meat packing companies. Due to the work of Dr. James Snyder and associates at Purdue, a large proportion of these short run decisions (indeed all of the short run decisions which are within the scope of an individual company) are actually being made, in some organizations, with the aid of analytical models. In this case rather than the analytical models abstracting from reality, these models are reality.

In this section we briefly review the analytical models which have been developed, published and implemented by Dr. Snyder and his group, and then discuss the modifications to existing models which would be needed for a fully coordinated organization.

Review

The programmed profit planning and control system for hog fabrication built by Snyder and Matthes[38] provides decision guides for routine analysis of fabrication operations on a daily or weekly basis.

This model uses an objective function which maximizes short run profit contribution.

Controllable alternatives included in the model can be grouped into four general categories: pricing, product mix, make or buy, and labor and plant utilization. These alternatives have been neatly illustrated in LP-schematic form by Snyder[38], see Table 2.

Pricing

It is assumed the company is a "price taker" in its fresh product sales. That is, the firm will sell whatever amount possible at the established market price. However, in branded products, there are some options in the model for "price-making" power. For example, the same product under different brand names may be entered as separate alternatives in the model. Also included in the model is a limited stepwise demand function, which permits additional products to be sold at a reduced price. For example, 500 pounds of sliced bacon may be sold at \$40.00 per hundredweight and an additional 100 pounds may be sold at a discounted price of \$36.00 per hundredweight.

Product Mix

A meat packer must balance the product mix of his purchasing activities with the product mix of his sales activities. The model permits the simultaneous evaluation of multitudinous weights-grades of live hogs available for purchase and an even larger number of primal and processed cuts available for sale.

Since many of the same primal cuts are obtained from different weight-grades, cost comparisons are difficult. Each slaughter, cut-out and conversion alternative involves joint products in fixed proportions. In evaluating expected returns from these alternatives, revenues from disposition of the final product are evaluated simultaneously with both acquisition and processing costs.

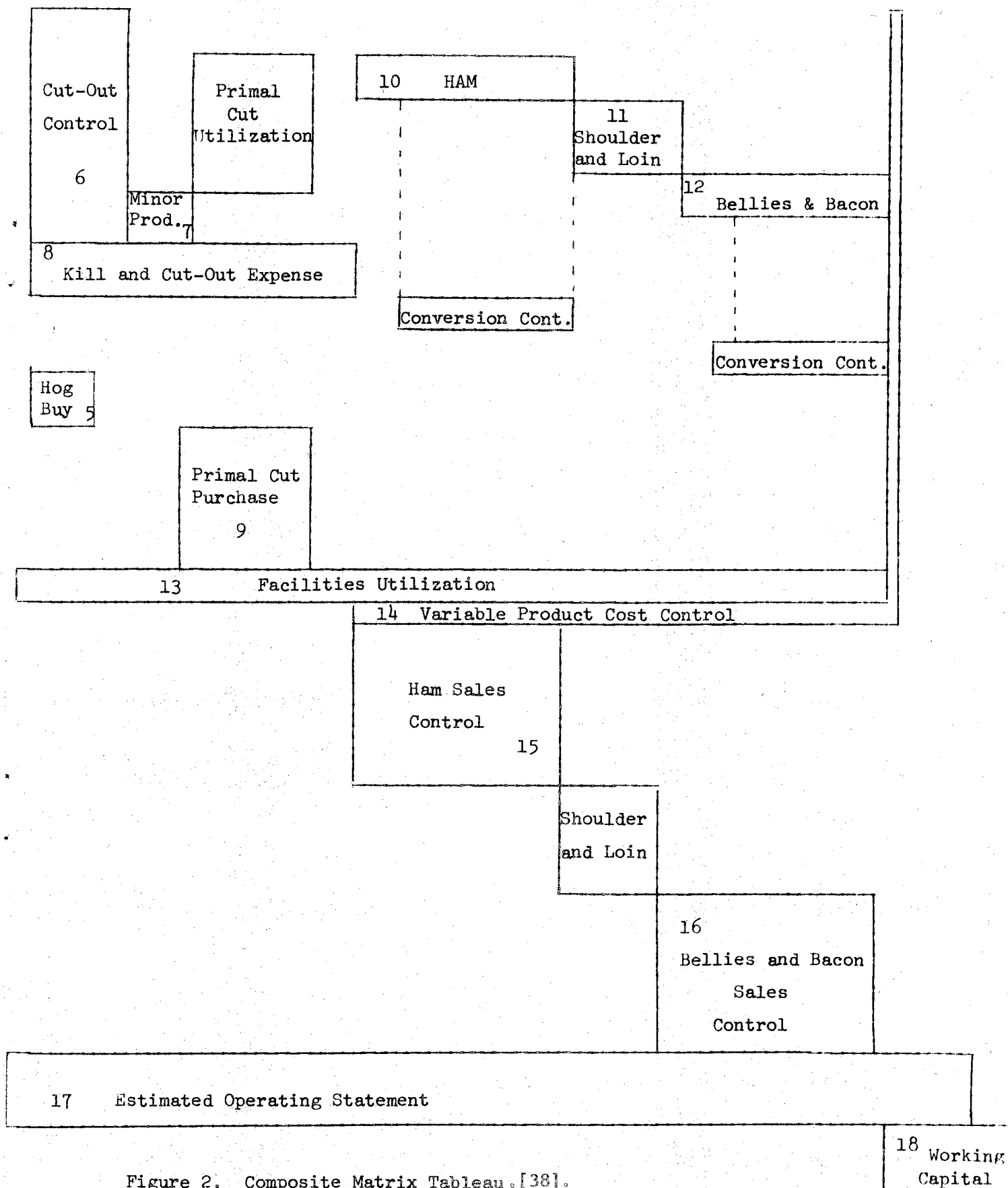


Figure 2. Composite Matrix Tableau, [38].

Hence, the model indicates the value to the system of each alternative weight-grade purchase option. Similarly, the model permits the evaluation of each alternative product sale option.

Make or Buy:

Packers are faced with fluctuations in hog supplies. Thus, a major decision is the kill level at which to operate. Often, it is profitable to buy primals from outside sources. By including outside purchase activities in the model, this source of supply is evaluated against that of obtaining primals from internal slaughter.

Labor and Facilities Utilization:

Bottlenecks in labor and equipment utilization can be analyzed effectively with the model. Kill line, smoke house, and bacon slicing are examples of functions which are subject to labor and equipment capacity restraints.

Actual industry applications of this model have involved systems with as many as 700 activities and 900 restraints. The major technical components of the model are: Hog procurement, Hog cut-out, Minor products disposal, Kill and cut-out expense, Primal cut purchase, Primal cut conversion and sale, Physical facilities utilization, Variable product cost, Product sales control, Estimated operating margin, and Working capital control. A schematic representation of these components is presented in Figure 1.

Additions

Potential additions to the profit planning and control model for hog fabrication are 1) a hog finishing components and 2) a retail fabrication component.

A hog finishing component would broaden the model to include the control of hog feeding. Alternative feeding programs and slaughter transfer weights could be incorporated into the model.

A retail fabrication component would likewise broaden the model to include detailed cut-up options on wholesale cuts for retail sale. Alternative marketing strategies could also be included in the retail fabrication component.

The effect of these additions would be to attempt coordination from the finishing to the retailing function whereas the basic fabrication model coordinates those activities between the purchase of live hogs and the sale of wholesale pork cuts.

Hog Finishing Component:

Information necessary to effectively model the hog finishing phase is basically biological data. For each group of hogs the following data are needed: inventory of hogs under control (control could be separated into owned, contracted, informally influenced); cost of feed under alternative feeding programs; gain in weight anticipated by the following planning period under alternative feeding programs (depending on how the model is used), this could be one week, two weeks, or a month); gain or loss of grade anticipated under alternative feeding programs; opportunity cost of hog finishing space per period; direct labor and materials cost (other than feed) of holding hogs another period.

Given this input information, the analysis available from an expanded hog fabrication model can guide decision-making in the areas of transfer weight, feed program, length of marketing period, feeder pig replacement purchases, and, over time, the blend of outside live hog purchases with inside hog transfers under changing ingredient, live hog, wholesale, and retail pork market conditions.

Retail Fabrication Component:

Information necessary to model the retail fabrication phase hinges on alternative retail cuts and consumer response to these cuts. For example, a pork loin can be divided into chops or roasts or a combination of both. The consumer response to these two retail products varies, depending upon many factors including season, price, advertising and promotion, and space allocation in the meat case as well as the basic buying needs of the individual consumer.

From this addition to the fabrication model, guidelines could be developed which would help answer retail product mix, pricing, promotion, and meat case space allocation questions.

SUMMARY

This bulletin has discussed some of the features of planning models which would be needed for any form of non-market vertical coordination of organizations in the hog-pork industry.

The focus has been on the major features of the management tools which would be needed by such an organization, if it were to function efficiently. These management tools would be needed regardless of the institutional form of the coordinating organization. The organization could be a cooperative, joint venture among partners, profit sharing agreement, or individual firm.

It should be emphasized that the models developed in this bulletin claim to achieve no more than can be achieved, at least in theory, by appropriately structured free marketing arrangements. The same "information" can be transmitted via price differentials, in a free market, as is arrived at in the sensitivity analysis of a formally structured model.

Free markets are the main institutional arrangement used at present to coordinate the hog-pork industry. The contribution of this bulletin has been to show that it appears to be technically feasible to achieve this coordination under one span of managerial control, and hence, in practice, with some improvement in the transmittal of information across functional interfaces.

The bulletin has drawn attention to the fact that formal short term (less than 3 weeks) planning models are already being used by some of the more progressive firms in the industry to coordinate the major portion of the short term decisions which have to be made. The increase in complexity required for intermediate and long term models does not appear likely to exceed the capacity of modern computers.

It should also be emphasized that operationally the short term models are the most difficult to implement because short term management guides which are delivered a week late are useless. For a short term model to be useful, results have to be available on the day they are asked for. For intermediate (or long term) models, operating performance which gave results in the week (or month) they were asked for, would probably be satisfactory.

We believe that the models presented in this bulletin show that managerial procedures exist for full integration of the hog-pork industry on the model of the broiler industry. The authors do not, at this stage, wish to take a

position on the desirability of such a restructuring of the industry. We do believe, however, that whether full integration is to be allowed is a very relevant policy question.

APPENDIX A

STRUCTURE OF A PROTOTYPE INTERMEDIATE-TERM PLANNING
MODEL FOR A VERTICALLY COORDINATED HOG-PORK PRODUCTION SYSTEM

The prototype presented here is a highly condensed representation of a possible operating intermediate-term planning model for a hog-pork production and marketing system. This condensation is not small, however. A total of 1133 structural activities and 780 constraints are contained in the model.

Overview

The model has 12 monthly periods, arranged sequentially, so that December follows November; January follows December; and February follows January. There are no opening or closing inventories, rather a consistent production pattern is sought which would meet the specified monthly retail pork requirements year after year.

The general strategy was to take retail demand as given, and to have the model attempt to meet this demand at least cost.

Whenever possible, restraints have been expressed as less than inequalities, so that negative matrix coefficients refer to the production of a product, and positive coefficients refer to use of a resource. Bounds were not used in the model, though many of the activities are suitable for bounding.

The 12 monthly periods result in an almost block diagonal matrix, as illustrated in Table A1.

Now, considering any of the monthly "A" matrices on the main diagonal, this matrix contains a number of submatrices as follows:

The composite model consists of 1133 sectors and 780 restraints. The basic submatrices number four. The functions of each of the submatrices are briefly discussed.

Submatrix A - This is the monthly allocation model. It is composed of 94 sectors and 60 rows. This matrix is the heart of the composite model and, therefore, is discussed in further detail in the following section.

Table A1: Schematic Representation of Prototype Hog-Pork Coordination Model

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
	-C _i (Objective Function)										F		bi
Jan	A D1	B	C										D ₂
Feb		A D1	B	C									E
Mar			A D1	B	C								
Apr				A D1	B	C							
May					A D1	B	C						
June						A D1	B	C					
July							A D1	B	C				
Aug								A D1	B	C			
Sept									A D1	B	C		
Oct										A D1	B	C	
Nov	C										A D1	B	
Dec	B	C										A D1	

Submatrix C - This portion of the composite model contains vectors which make the model intertemporal between non-adjacent months. This submatrix has an even lower density, containing only two bacon storage activities.

Submatrix D - This submatrix contains the annual capacity restraints. These restraints number five and are composed of three finishing capacity restraints, one slaughter capacity restraint, and one freezer storage restraint.

There are two parts to this component of the model. D_1 is part of the monthly activity, and D_2 is composed of five annual activities into which the monthly components are transferred.

Submatrix E - This section contains the restraints, all of which are zero except for the 20 monthly demand minimums. Thus, 240 restraints are positive numbers and 540 contain zero elements.

Submatrix F - This section contains the objective function, which is a minimization function. All the 1133 coefficients are either negative or zero. This submatrix contains the following parts:

1. Ingredient purchase and feed formulation
2. Feeder pig procurement
3. Feeding programs
4. Housing systems
5. Hog slaughter
6. Primal cut conversion, purchase and storage: ham
7. Primal cut conversion, storage, and transfer to retail: bacon
8. Primal cut conversion and transfer to retail: loin,
9. Production, slaughter, and storage capacities, and
10. Marketing.

The general arrangement of these submatrices within one of the main diagonal matrices can be seen from Table A2. Basically, the submatrices in Table A2 refer to activities taking place within a month (though, as is explained below, a few have implications, such as feed purchase or product storage, beyond the month actually being considered). We now turn to the consideration of the individual submatrices.

Feed Formulation

Activities j equals 1 and 2 represent two key swine feed ingredients - corn and soybean meal. Each ingredient contributes both protein and energy, but in different quantities. (It is important to emphasize that the values of protein and energy contributed by corn in Table A3 are scaled by a factor of 10.) This simple least-cost formulation of swine feed could be expanded to include many other ingredients. However, on-the-farm mixing generally is limited to several ingredients; hence, so is this component of the model.

Feeder Pig Procurement

Activities j equals 3 and 4 represent purchase of feeder pigs of two different qualities. There is no limit on the quantity of feeder pigs of each quality available.

The only constraint on feeder pig purchase is that for every market hog produced, 105 feeder pig must be purchased. In this manner, a mortality figure of approximately 5% is represented in the model in the two constraints, i equals 3 and 4.

Quality

Activities j equals 17 and 19 represent two market hogs of the same weight but different quality.

Quality is defined on two dimensions: feed conversion and carcass quality. Constraints i equals 1 and 2 describe the protein and energy requirements of both the high and the low quality feeder pigs. Constraints i equals 5 and 6 describe the percentages of high and low quality carcasses which result from the two alternative feeder pig qualities.

Thus, this aspect of the model assesses the trade-off between high and low quality feeder pig purchase. Costs being equal, the high quality feeder pig is a better choice, since both feed conversion and percentage of quality carcasses produced are higher.

Feeding Programs

Activities j equals 5 to 16 represent a limited feeding program in which major emphasis is placed on feed conversion while activities j equals

Table A2. Summary of "Within Month" Activities

j =	1-2	3-4	5-28	29-32	33-38	39-66	67-70	71-74	75-85	85-94
	Ingredi- ent Pur- chase	Feeder Pig Pur- chase	Hog Finish- ing	Hog Slaugh- ter	Bacon Trans- fer	Ham Trans- fer	Loin Trans- fer	Bacon Stor- age	Market 1 Distribution	Market 2
i =										
1-2 Feed Formulation	1		4							
3-4 Finishing		2								
4-8 Hog Finishing Quality			3							
9-12 Ham Primal Cut-out				5						
13-20 Ham Transfer and Stor.					6					
21-24 Loin Primal Cut-out							8			
25-30 Loin and Ham Ret. Cut-out						6				
31-32 Bacon Cut-out					7					
33-38 Bacon Transfer and Stor.								7		
39-40 Whole and Rolled Ham Trans.						6				
41-50 Retail Utilization-Market 1									10	
51-60 Retail Utilization-Market 2										

1. Ingredient Purchase and Feed Formulation
2. Feeder Pig Procurement, Mortality, Feed Consumption, and Carcass Quality
3. Feeding Program and Housing Systems
4. Housing Capacity
5. Hog Slaughter
6. Primal Cut Conversion, Purchase and Storage: Ham
7. Primal Cut Conversion, Storage and Transfer to Retail: Bacon
8. Primal Cut Conversion and Transfer to Retail: Loin
9. Production, Slaughter and Storage Capacities
10. Marketing

Table A3. Feed Formulation, Feeder Pig Procurement, Quality Feeding Programs, and Housing Systems

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Ingredient		Pigs		Limited Feeding Program											
	Corn	S.B.M.	H.Q.	L.Q.	Conventional				Partially Slotted				Fully Slotted			
					H.Q.		L.Q.		H.Q.		L.Q.		H.Q.		L.Q.	
					210	230	210	230	210	230	210	230	210	230	210	230
1. Protein	-8.5	-51.			62.58	73.73	64.73	75.88	62.58	73.73	64.73	75.88	62.58	73.73	64.73	75.88
2. Energy	-3.8	- .5			16.56	17.01	17.47	17.92	16.56	17.02	17.47	17.92	16.56	17.01	17.47	17.92
3. High Quality Feeder Pig			-1		1.05	1.05			1.05	1.05			1.50	1.50		
4. Low Quality Feeder Pig				-1			1.05	1.05			1.05	1.05			1.05	1.05
5. 210# No. 1 Carcass					-.90		-.80		-.90		-.80		-.90		-.80	
6. 210# No. 2 Carcass					-.10		-.20		-.10		-.20		-.10		-.20	
7. 230# No. 1 Carcass						-.80		-.70		-.80		-.70		-.80		-.70
8. 230# No. 2 Carcass						-.20		-.30		-.20		-.30		-.20		-.30

Table A3 (cont'd). Feed Formulation, Feeder Pig Procurement, Quality Feeding Programs, and Housing Systems

	17	18	19	20	21	22	23	24	25	26	27	28
	Fast Feeding Program											
	Conventional				Partially Slotted				Fully Slotted			
	H.Q.	L.Q.			H.Q.	L.Q.			H.Q.	L.Q.		
	210	230	210	230	210	230	210	230	210	230	210	230
1. Protein	85.05	85.15	87.2	88.3	85.05	85.15	87.2	88.3	85.05	85.15	87.2	88.3
2. Energy	18.49	19.0	19.4	19.91	18.49	19.0	19.4	19.91	18.49	19.0	19.4	19.91
3. High Quality Feeder Pig	1.1	1.1			11.	11.			11.	1.1		
4. Low Quality Feeder Pig			11.	11.			11.	11.			1.1	11.
5. 210# No. 1 Carcass	-.90		-.80		-.90		-.80		-.90		-.80	
6. 210# No. 2 Carcass	-.10		-.20		-.10		-.20		-.10		-.20	
7. 230# No. 1 Carcass		-.80		-.70		-.80		-.70		-.80		-.70
8. 230# No. 2 Carcass		-.20		-.30		-.20		-.30		-.20		-.30

17 to 28 represent a feeding program designed to minimize the time required to reach market weight. The former program requires four months to finish weights, but yields a better feed conversion ratio than the latter program which requires only three months to finish the hogs to market weights. There is no difference in the quality of carcass or the mortality rates produced by the two alternative feeding programs. (At this time, these relationships are hypotheses and not scientific fact based on biological research data.)

Housing Systems

Activities j equals 5 to 8 and 17 to 20 model a conventional swine finishing unit, activities j equals 9 to 12 and 21 to 24 model a partially slotted finishing unit, and activities j equals 13 to 16 and 25 to 28 model a totally slotted finishing unit. The major differences in the systems (other than cost, which will be discussed later) is the mortality rate. The conventional housing system creates considerably less mortality than the other two systems.

The capacity of each housing system is 800 head when the system is operating. Each system operates on a separate monthly schedule, as follows:

Table A4. Housing Capacity, by Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Conven- tional					X	X	X	X				
Partially Slotted*			X	X	X	X	X	X	X	X		
Totally Slotted	X	X	X	X	X	X	X	X	X	X	X	X

* The partially slotted technology is an open partially slotted house.

However, the model is designed to calculate costs as finished hogs marketed. Thus, the following marketing months are available for each system. (Table A5) The number of months available for marketing hogs under each system depends on whether a three or four month feeding program is used.

Table A5. Marketing Capacities of Alternative Housing Systems, by Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
<hr/>												
Fast Feeding												
<u>Program</u>												
3-Month												
Conventional							X	X				
Partially Slotted					X	X	X	X	X	X	X	X
Fully Slotted	X	X	X	X	X	X	X	X	X	X	X	X
<hr/>												
Slow Feeding												
<u>Program</u>												
4-Month												
Conventional								X				
Partially Slotted						X	X	X	X	X	X	X
Fully Slotted	X	X	X	X	X	X	X	X	X	X	X	X

Hog Slaughter

This partition specifies the cutout yield from four different weight-grades of hog. Activities j equals 29, 30, 31, and 32 represent hundredweights of slaughtered hog. These carcasses yield different percentages of weight and grade of primal cuts. (Table A6)

For example, a 210# high quality live hog (No. 1 grade) yields 12.55% 10/12 lb. ham and only 5.72% 12/14 lb. ham, while a 230# high quality live hog yields only 1.2% 10/12 lb. ham and 15.7% 12/14 lb. ham.

As the hogs are transferred into hog slaughter the head count is converted to hundredweight. The transfer constraints balance hog slaughter with hog finishing. Total hundredweight of hogs slaughtered in a given month must equal an equivalent number of head of hogs finished in that month.

Table A6. Hog Slaughter

j =		5	6	7	8	29	30	31	32
		210#	230#	210#	230#	210#	210#	230#	230#
		High		Low		High	Low	High	Low
		Quality	Market	Hog		Quality	Market	Hog	
		(%)	(%)	(%)	(%)	No.1	No.2	No.1	No.2
						(cwt.)	(cwt.)	(cwt.)	(cwt.)
1 =									
5	210# No.1(Head)	-.90		-.80		.476			
6	210# No.2(Head)	-.10		-.20			.476		
7	230# No.1(Head)		-.80		-.70			.435	
8	230# No.2(Head)		-.20		-.30				.435
9	10/12 High Quality Hams (lbs.)					-12.55		-1.24	
10	10/12 Low Quality Hams (lbs.)						-13.19		- 7.22
11	12/14 High Quality Hams (lbs.)					- 5.72		-15.70	
12	12/14 Low Quality Hams (lbs.)						- 1.09		-10.37
21	8/12 High Quality Loins (lbs.)					-12.48		- 3.08	
22	8/12 Low Quality Loins (lbs.)						-14.06		- 9.35
23	12/16 High Quality Loins (lbs.)					- 3.13		-12.72	
24	12/16 Low Quality Loins (lbs.)						- 1.43		- 5.33
31	High Quality Bacon (lbs.)					-10.72		- 7.3	
32	Low Quality Bacon (lbs.)						-10.92		- 5.39

Primal Cut Conversion, Purchase, and Storage; Ham: (Table A7) This partition represents the use of ham primals for fresh whole ham j equals 55 to 58; rolled ham, j equals 59 to 62; and sliced ham pork products, j equals 63 to 66. In addition to ham primals transferred from slaughtering operations, j equals 29 to 32, ham primals can be purchased, j equals 39 to 42. Also, ham primals can be transferred out of previous period storage, j equals 51 to 54, and simultaneously be transferred into storage for usage in the following month, j equals 47 to 50, and March 51 to 54, respectively.

Primal Cut Conversion, Storage, and Transfer to Retail; Bacon: (Table 8) This partition represents the retail utilization of bacon. In this model, bacon can be stored two months. Hence, bacon utilization in the current month can be supplied from current slaughter and/or storage from one to two months prior to the current month.

Activities, j equals 29 to 32, represent bacon primals derived from slaughter. Activities, j equals 71 to 74 represent bacon stored one and two months, respectively. Activities, j equals 81, 82 and 91, 92 show current usage of bacon at retail.

Surplus bacon can be stored for one or two months, as presented by the 8 activities, j equals 35 to 38 and March 73, 74 and April 71, 72.

The restraints, i equals 31 to 38 balance this transfer process to insure that no more bacon is utilized and stored than is slaughtered and taken from storage.

		February																				March															
		29	30	31	32	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	51	52	53	54
		210#	210#	230#	230#	Ham		Ham		Ham		Ham		Retail		Retail		Retail		Retail		Retail		Retail		Retail		Retail		Retail		Retail		Retail			
		No.1	No.2	No.1	No.2	Purchase		Transfer		Storage		Out		Storage		In		Ham		Transfer		Transfer		Transfer		Transfer		Transfer		Transfer		Transfer					
		Slaughter	Hog	Slaughter	Hog																																
		(cwt.)	(cwt.)	(cwt.)	(cwt.)	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.	Qu.	Av.		
1	10/12 Qu.	-12.55		-1.24				1				1																									
	Ham Cut-out																																				
10	10/12 Av.		-13.19		-7.22			1				1																									
	Ham Cut-out																																				
11	12/14 Qu.	-5.72		-15.70						1				1																							
	Ham Cut-out																																				
12	12/14 Av.		-1.09		-10.37						1				1																						
	Ham Cut-out																																				
13	10/12 Ham Transfer					-1			-1						-1			1				2				1											
14	10/12 Ham Transfer					-1			-1						-1			1				2				1											
15	12/14 Ham Transfer						-1		-1							-1			1				2				1										
16	12/14 Ham Transfer							-1			-1						-1			1			2					1									
17	10/12 Qu. Ham Storage											-1																						1			
18	10/12 Av. Ham Storage												-1																						1		
19	12/14 Qu. Ham Storage														-1																				1		
20	12/14 Av. Ham Storage															-1																			1		

Table A8. Primal Cut Conversion, Storage, and Transfer to Retail: Bacon

[illegible]

Retail Transfer and Conversion: Loin: This partition describes the transfer of the loin primal to retail and its division into pork chops and loin roasts. (Table 19)

Activities j equals 29, 30, 31 and 32 represent four weight-grades of slaughter hog. Activities j equals 67, 68, 69 and 70 are transfer and conversion activities which divide the wholesale primal loin cut into two weights of chops and roasts. The quality differentiation is not maintained at the retail level since the loin is a muscle cut whose quality is not reflected by carcass quality.

Activities j equals 77, 78, 79 and 80 represent the distribution of the four loin retail products to market 1 and activities 87, 88, 89 and 90 represent the distribution to market 2.

Constraints i equals 21, 22, 23 and 24 model the percentage cut-out of loin primals and balance the utilization of retail loin cuts with wholesale loin primals generated from hog slaughter. The pounds of retail pork cuts utilized times the retail cut-out percentages must equal or be less than the hundredweights of hogs slaughtered times the wholesale cut-out percentages.

For example, every 24 pounds of large pork chop sold at retail, activities j equals 78 and 88, requires a 100 pounds of heavy loin primal, activities j equals 29, 30, 31 and 32. Every weight-grade of slaughter hog yields some percentage of heavy loin, but the highest percentage (12.72%) is produced by the 230 pound No. 1 slaughter hog, activity j equals 31.

Table A9. Retail Transfer and Conversion: Loin

j =	29	30	31	32	67	68	69	70	77	78	79	80	87	88	89	90
	210# No.1	210# No.2	230# No.1	230# No.2	Transfer of Wholesale Cut to Retail Conver- sion				Market 1 Retail Loin Cuts				Market 2 Distribution			
	Hog Slaughter															
i =																
21 8/12 loin cut-out	-12.48		-3.08		1											
22 8/12 loin cut-out		-14.06		-9.35		1										
23 12/16 loin cut-out	-3.13		-12.72				1									
24 12/16 loin cut-out		-1.43		-5.33				1								
27 Regular Pork Chops (lb.)					-.24	-.24			1				1			
28 Large Pork Chops (lb.)							-.24	-.24		1				1		
29 Regular Pork Roasts (lb.)					-.20	-.20					1				1	
30 Large Pork Roasts (lb.)							-.20	-.20				1				1

Production, Slaughter, and Storage Capacities: This partition models the annual capacities required for production, slaughter, and storage facilities. (Table A 10)

The balancing constraints, i equals 61 to 65, add one unit of capacity for each hog produced, each hundredweight slaughtered, or each pound stored.

The activities, i equals 1120 to 1133, capture the highest capacity required in any one month of the 12 month period and purchases that amount of capacity. This results in an annual purchase of capacity rather than a monthly purchase.

Marketing

The only restraints on the equations in this model which have numerical values other than zero are the product demand restraints. For 10 pork products in two markets in each of 12 months, a specific demand figure has been inserted in the model. These figures are contained in Table A11.

All the other restraints are equal to or less than zero constraints. The advantage of using a less than or equal to rather than an equal to restraint is that it permits slight inequalities rather than forcing an infeasible solution. Slight inequalities sometimes occur when the balancing equation contains small numbers and large numbers i.e. head of hogs vs. pounds of ingredients.

Costs

The major costs in this model are on the following activities: Corn, protein supplement, feeder pigs, housing systems (including some very high costs when a system was inoperative in a particular month), ham purchase, and production, slaughtering, and storage capacity. These costs for the 12-month period are listed in Table A12.

Table A10. Production, Slaughter, and Storage Capacities

j =	4	9	13	31	51	73	4	9	13	31	51	73	1129	1130	1131	1132	1133
	Conven- tional Slot	Par- tial Slot	Full Slots	210# Slaughter Hog	Ham Stor- age	Bacon Stor- age	Conven- tional Slot	Par- tial Slot	Full Slots	210# Slaugh- ter Hog	Ham Stor- age	Bacon Stor- age	Conven- tional	Partial Slots	Fully Slot- ted	Slaugh- ter	Stor- age
Capacity Purchased																	
i =																	
Feb.																	
61 Conventional Production Capacity	1						1						-1				
62 Partially Slotted		1						1						-1			
63 Fully Slotted			1						1						-1		
64 Slaughtering Capacity				1						1						-1	
65 Storage Capacity					1	1					1	1					-1
March																	
61 Conventional Production Capacity	1						1						-1				
62 Partially Slotted		1						1						-1			
63 Fully Slotted			1						1						-1		
64 Slaughtering Capacity				1						1						-1	
65 Storage Capacity					1	1					1	1					-1

Table All. Product Demand Restraints, by Months (in 1000 pound units)

	J	F	M	A	M	J	J	A	S	O	N	D
i -												
Row												
<u>High Income Mkt.</u>												
41 Ham C. Slice LN	807	707	865	807	660	660	661	694	760	751	752	707
42 Ham C. Slice RG	89	77	95	89	72	72	72	76	83	82	82	77
43 Pork Chop RG	242	212	259	242	198	198	198	208	228	225	225	212
44 Pork Chop LG	566	495	606	566	463	463	463	486	533	526	527	495
45 Pork Roast RG	156	136	167	156	128	128	128	134	147	145	145	136
46 Pork Roast LG	234	205	251	234	192	192	192	201	221	218	218	205
47 Bacon No. 1	798	698	855	798	653	653	653	686	751	742	743	698
48 Bacon No. 2	199	174	213	199	163	163	163	171	187	185	185	174
49 Whole Ham	293	256	314	293	240	240	240	252	276	273	273	256
50 Rolled Ham	321	281	344	321	263	263	263	273	303	299	299	281
<u>Low Income Mkt.</u>												
51 Ham C. Slice LN	1393	1219	1493	1393	1140	1140	1142	1198	1312	1296	1297	1219
52 Ham C. Slice RG	174	152	186	174	142	142	142	149	163	161	162	152
53 Pork Chop RG	575	503	616	575	470	470	471	494	541	535	536	503
54 Pork Chop LG	864	756	926	864	707	707	708	743	814	802	806	756
55 Pork Roast RG	293	256	314	293	240	240	240	252	276	273	273	256
56 Pork Roast LG	293	256	314	293	240	240	240	252	276	273	273	256
57 Bacon No. 1	185	162	199	185	152	152	152	159	174	171	173	162
58 Bacon No. 2	1740	1523	1865	1740	1424	1424	1425	1496	1639	1616	1623	1523
59 Whole Ham	264	231	282	264	216	216	216	227	248	244	246	231
60 Rolled Ham	361	316	387	361	296	296	296	311	340	334	338	316
Total	9780	8560	10480	9750	8000	8000	8050	8410	9210	9080	9120	8560

Table A12. Costs, by Month and Annual

j =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Corn	Soy- bean Meal	Feeder Pigs Hi Lo Grade		Single Season Single Season Far- rowing (Conventional) Four Weight Grades of Hogs				Multiple Season Multiple Season Farrowing (Partial Slots)				Year Round Farrowing (Fully Slotted) Four Weight Grades of Hogs			
Slow Feeding Program																
	\$/cwt.	\$/cwt.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.	\$/hd.
Jan.	1.94	5.00	13.	10.	100.	100.	100.	100.	100.	100.	100.	100.	4.17	4.17	4.17	4.17
Feb.	1.95	--	14.	12.	"	"	"	"	"	"	"	"	"	"	"	"
Mar.	1.97	--	15.	14.	"	"	"	"	"	"	"	"	"	"	"	"
Apr.	1.94	5.05	17.	16.	"	"	"	"	"	"	"	"	"	"	"	"
May	1.96	5.00	16.	14.	"	"	"	"	"	"	"	"	"	"	"	"
June	1.97	4.95	15.	11.	"	"	"	"	4.80	4.80	4.80	4.80	"	"	"	"
July	1.98	5.15	13.	9.	"	"	"	"	"	"	"	"	"	"	"	"
Aug.	2.00	5.10	14.	11.	5.75	5.75	5.75	5.75	"	"	"	"	"	"	"	"
Sept.	2.00	5.05	14.	13.	100.	100.	100.	100.	"	"	"	"	"	"	"	"
Oct.	1.91	4.95	15.	14.	"	"	"	"	"	"	"	"	"	"	"	"
Nov.	1.88	4.85	16.	15.	"	"	"	"	100.	100.	100.	100.	"	"	"	"
Dec.	1.94	4.90	17.	16.	"	"	"	"	"	"	"	"	"	"	"	"
Annual																

Table A12.(cont'd.)

	17	18	19	20	21	22	23	24	25	26	27	28	39	40	41	42	1129	1130	1131	1132	1133
	Single Season Farrowing (Conventional)				Multiple Season Farrowing (partial slots)				Year Round Farrowing (Fully slotted) Four Weight Grades of Hogs				Outside Purchase of Hams - 4 Weight Grades				Building Capacity Purchase Annually		Slau-ghter capacity	Freezer capacity	
	Fast Feeding Program																		purchase annually	purchase annually	
	\$/Lb.																\$/hd.	\$/hd.	\$/Lb.	\$/Lb.	
Jan.	100.	100.	100.	100.	100.	100.	100.	100.	3.50	3.50	3.50	3.50	.50	.50	.50	.50					
Feb.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
Mar.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
Apr.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
May	"	"	"	"	4.00	4.00	4.00	4.00	"	"	"	"	"	"	"	"					
June	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
July	4.41	4.41	4.41	4.41	"	"	"	"	"	"	"	"	"	"	"	"					
Aug.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
Sept.	100.	100.	100.	100.	"	"	"	"	"	"	"	"	"	"	"	"					
Oct.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
Nov.	"	"	"	"	100.	100.	100.	100.	"	"	"	"	"	"	"	"					
Dec.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"					
Annual																	.72	1.95	2.11	.005	.01

APPENDIX B

Table B1. Listing of Monthly Solution Values Prototype Model.

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	Corn Purchased (cwt.)	4763	1966	1339	650	497	2177	4255	2261	1970	1253	1176	
2	Protein Supp. (cwt.)	813	291	166	62	87	383	724	370	310	155	146	
4	Av. Feeder Pigs (head)	1011	436	292	140	101	442	908	506	439	273	258	
15	Av. 4 month 210# Finished Hog Totally Slotted System		466	335	121				458	502	394	113	106
16	Av. 4 month 230# Finished Hog			98	170	139					41	159	149
23	Av. 3 month 210# Finished Hog Partly Slotted System							110					
27	Av. 3 month 210# Finished Hog Totally Slotted System (head)	533				99	436	328					
29	Lt. Wt. No. 1 Car.(cwt.)	896	784	563	204	167	733	738	771	844	663	191	179
30	Lt. Wt. No. 2 Car.(cwt.)	224	196	140	51	41	183	184	192	211	165	47	44
31	Hv. Wt. No. 1 Car.			157	273	224					67	256	240
32	Hv. Wt. No. 2 Car.			67	117	96					28	109	103
33	Lean Bacon to Ret.(lbs.)	9612	8413	7195	4190	804	804	809	845	925	912	916	860
34	Reg. Bacon to Ret.(lbs.)	1674	982	1294	1190	976	1586	1179	1667	867	1007	849	738
36	Reg. Bacon to Feb. Storage (lbs.)	407	417				416		123	479			
37	Lean Bacon to Mar. Storage (lbs.)					2633							
38	Reg. Bacon to Mar. Storage (lbs.)	365	742	609				835	313	958	958	264	307
39	10/12 Qu. Ham Pur.			10934				4308			7330	14840	
40	10/12 Av. Ham Pur.					118			686			1406	
41	12/14 Qu. Ham Pur.	3617	3166		17370	14133	4410		2421	3572			14275
42	12/14 Av. Ham Pur.	660	727	1418						1046			1669
43	10/12 Qu. Ham Cut-out (lbs.)	11253	9849	7271	2903	2382	8662	9262	9676	10431	8407	2716	2549
44	10/12 Av. Ham Cut-out (lbs.)	2956	2587	2347	1521	1248	2418	2433	2542	2784	2395	1423	1335

Table B1. (cont'd.)

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
45	12/14 Qu. Ham Cut-out (lbs.)	5128	4489	3225	1168	958	4195	3463	4410	4829	3793	1093	1026
46	12/14 Av. Ham Cut-out		213	854	1273	1044	199		210	230	479	1190	423
47	10/12 Av. Ham Feb. Stor.						542			165			
49	12/14 Av. Ham Feb. Stor.							757					
50	12/14 Qu. Ham Feb. Stor.	244						757					694
51	10/12 Av. Ham Dec. Stor.							201			165		
53	12/14 Av. Ham Dec. Stor.								757				
54	12/14 Qu. Ham Dec. Stor.	694	244					542	201				
55	Av. Whole Ham to Retail				144		255		67				
56	Av. Whole Ham to Retail	557	497	596						524			487
57	Qu. Whole Ham to Retail							458			517		
58	Qu. Whole Ham to Retail				411	455	199		411			519	
59	Rolled Ham to Retail				679	557	326	328			305		172
60	Rolled Ham to Retail	682	596	730			231	232	586	642	87	635	424
62	Rolled Ham to Retail										239		
63	Ln. Sl. Ham to Retail	11253	9849	18206	1399	1266	7753	13456	9609	10431	15291	17557	2203
64	Rg. Sl. Ham to Retail	1035	906	288	1521	1366	1955	1967	2055	975	2219	1558	
65	Ln. Sl. Ham to Retail	8746	7655	3225	18538	15032	8606	3005	7589	8402	3726	1093	15301
66	Rg. Sl. Ham to Retail	1355	1186	2273	862	589				1276		671	2092
68	Rg. Loin to retail	11190	9794	7522	3393	2784	9153	9201	9622	10538	8484	3174	2979
69	Lg. Loin to Retail	3151	2758	2613	1815	1430	2578	2594	2710	2968	2600	1698	1594
70	Lg. Loin to Retail	2806	2456	3770	4124	3383	2295	2310	2413	2642	2931	3857	3620
72	Lean Bacon From Nov. Stor.	264	307	365	742	609				835	313	958	958
74	Reg. Bacon From Nov. Stor.			407	417				416		123	479	
75	Lean Ham Center Slices	807	706	864	804	660	660	664	693	759	749	752	706
76	Reg. Ham Center Slices	89	77	95	88	72	72	73	76	83	82	82	77
77	Reg. Pork Chops	2110	211	1189	241	197	1726	199	208	227	224	225	211
78	Large Pork Chops	566	495	606	564	462	462	465	486	533	525	527	495
79	Reg. Pork Roasts	156	1702	1190	386	127	127	1601	1672	146	142	361	339
80	Lg. Pork Roasts	898	786	250	895	191	735	739	201	220	834	838	786
81	Lean Bacon	9427	698	6997	4005	652	652	656	686	751	740	744	698
82	Reg. Bacon	199	174	213	198	162	162	163	171	187	184	185	174
83	Whole Hams	293	256	313	292	239	239	241	251	275	272	273	256
84	Rolled Hams	321	280	343	320	262	262	264	276	302	298	299	280

Table B1. (cont'd.)

Code	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
85	Lean Ham Center Slices	1393	1219	1492	1388	1139	1139	1146	1197	1311	1293	1298	1219
86	Reg. Ham Center Slices	174	152	186	173	142	142	143	149	163	161	162	152
87	Reg. Pork Chops	575	503	616	573	470	470	2011	2101	2301	533	536	503
88	Lg. Pork Chops	864	756	925	861	706	706	711	742	813	802	805	756
89	Reg. Pork Roasts	293	256	313	292	429	239	241	251	275	272	273	256
90	Reg. Pork Roasts	293	256	1026	292	783	239	241	823	901	272	273	256
91	Lean Bacon	185	161	198	184	151	151	152	159	174	171	172	161
92	Reg. Bacon	1740	1522	1864	1734	1423	1423	1423	1496	1638	1615	1622	1522
93	Whole Hams	264	231	282	263	215	214	217	227	248	245	246	231
94	Rolled Hams	361	315	386	359	295	295	297	310	339	335	336	315

APPENDIX C

RESTRAINT COUNT FOR AN OPERATIONAL INTERMEDIATE-TERM PLANNING MODEL

The estimated number of restraints in an operational intermediate-term planning model of the hog-pork subsector is 3276, or 273 per month.

A listing of these restraints is contained in Table B1 which accompanies the following brief discussion of each model component.

Ingredient Purchase: 2 nutrients, protein and energy, comprise the simplified least-cost feed mixing problem. Although the activities have been expanded in the operational model compared to the prototype model, the number of restraints remains the same.

Feeder Pig Procurement: 4 feeder pig procurement sources are used, 3 representing alternative farrowing systems using different breeding stock, and 1 representing the quality of feeder pigs available as a purchased input.

Gilt Replacement: As 3 types of breeding stock are modeled, one for each farrowing system, 3 restraints are needed to balance the acquisition and disposition of the breeding herd.

Hog Finishing: 48 restraints are needed to model

24 weight-grades of feeder hogs and the 24 weight-grades of reproduction stock. While this appears to be a large number of categories, it is the minimum number which is being used in operational models being employed by meat packers who have adopted this technique.

Hog Slaughter: 72 restraints are needed in this component to transfer 72 weight-grades of primals to wholesale and retail processing activities. These 72 restraints are comprised of 24 ham restraints, 16 loin restraints, 12 Boston butt restraints, 12 picnic restraints, and 8 belly restraints.

Primal Purchase: 20 purchase restraints are included in this component of the model, which consists of low quality primals. The 20 restraints are divided as follows: ham, 6; loin, 4; butt, 3; picnic, 3; and bell, 4.

Primal Storage: Bacon and ham are the only primals which have storage restraints. Bacon is storable for two months and ham for one month. The storage restraint equations number 16 for bacon and 24 for ham, for a total of 40.

Processing: 38 processing activities are included. These are made up of 7 retail ham, 13 retail loin, 8 retail bacon, 4 retail butt, and 6 retail picnic product.

Distribution: 38 retail products are distributed and are controlled with 38 product demand restraints.

STRUCTURE OF A PROTOTYPE INTERMEDIATE-TERM PLANNING MODEL FOR A VERTICALLY COORDINATED HOG-PORK PRODUCTION SYSTEM

The prototype presented here is a highly condensed representation of a possible operating intermediate-term planning model for a hog-pork production and marketing system. This condensation is not small, however. A total of 1133 structural activities and 780 constraints are contained in the model.

Overview

The model has 12 monthly periods, arranged sequentially, so that December follows November; January follows December; and February follows January. There are no opening or closing inventories, rather a consistent production pattern is sought which would meet the specified monthly retail pork requirements year after year.

The general strategy was to take retail demand as given, and to have the model attempt to meet this demand at least cost.

Whenever possible, restraints have been expressed as less than inequalities, so that negative matrix coefficients refer to the production of a product, and positive coefficients refer to use of a resource. Bounds were not used in the model, though many of the activities are suitable for bounding.

The 12 monthly periods result in an almost block diagonal matrix, as illustrated in Table A1.

Now, considering any of the monthly "A" matrices on the main diagonal, this matrix contains a number of submatrices as follows:

The composite model consists of 1133 sectors and 780 restraints. The basic submatrices number four. The functions of each of the submatrices are briefly discussed.

Submatrix A - This is the monthly allocation model. It is composed of 94 sectors and 60 rows. This matrix is the heart of the composite model and, therefore, is discussed in further detail in the following section.

Submatrix B - This portion of the composite model contains the sectors which make the model intertemporal between adjacent months. This submatrix has a very low density as only 6 vectors are filled with non-zero elements. The 6 vectors are the four ham and two bacon storage activities.

FOOTNOTES

* With the usual caveat the authors acknowledge the constructive suggestions of Bill Morris and Jim Snyder.

- 1/ Every author seems to have his own favorite phrase to describe closer vertical coordination, ranging from the "systems" approach to "sub-sector" analysis to "vertigration". Policy-coordination is our phrase to describe this phenomenon. Price-coordination, on the other hand, refers to the more traditional organization, where feeder pig, finished hog, green cut, and wholesale product market are used to transfer product from farmer to consumer, and information from consumer to farmer.
- 2/ For a full review of industry thinkers on the prospects for and pitfalls of non-market coordination in the swine industry, see [38].
- 3/ "Those (hogs) that normally go to market at that time of the year (fall) would be held back to consume corn. Then, when they do come in, the hogs are not only heavier, but fatter, too. The packer, in turn, must ship heavier cuts than your order called for rather than short your (retails) order. There is little that can be done to change this." [8, p. 45]
- 4/ Point out that based on farm records of Indiana hog farmers the maximum economics of scale are reached at low levels in hog enterprises (35-45 sows). The study states that very few operators in the Midwest can handle over 200 sows, while some European operations run 500-800 sows. The difference is attributed to the scarcity of high quality labor.[11]
- 5/ One alternative which might be considered is portable facilities, see [16] or [17].
- 6/ This statement based on the following pro forma financial outline.

Financial Outline			
10,000 Hog-1 Million Dollar Pork Entity (000)			
Total Retail Sales	\$1,000	Retail Margin (20%)	\$ 200
(100 lbs. of retail pork per		Packer Margin (30%)	300
hog, at \$1.00 per lb.)		Feeding Margin(20%)	200
(Comprised of:		Feeder Pig Pro-	
23% ham, 22% belly, 9% butt,		duction Margin(30%)	300
20% loin, 11% picnic, 15% misc.)			
	<u>\$1,000</u>		<u>\$1,000</u>
Total Assets	\$1,000	Boar Inventory	\$ 10
(Based on 30 boars, 600 sows,		Sow Inventory	30
1000 pigs, 500 hogs, and		Pig Inventory	20
2000 cwt. primals)		Hog Inventory	100
		Primal Inv.	140
		Breeding Farm	100
		Milling Facilities	100
		Farrowing Buildings	100
		Finishing Buildings	200
		Packing Plant	100
		Retail Meat Cases	100
	<u>\$1,000</u>		<u>\$1,000</u>

7/ For a thorough exposition of this new technology in the context of a related agri-business see [18].

8/ One possible formula suggested by a feed manufacturer: The basic inputs are: Pig supplier--feeder pigs; feed dealer--feed, medication, and other costs; producer--building, equipment, labor. All costs are charged to the project at retail to computer profit plus interest. Returns are split as follows: Producer, $1/2$; feed dealer, $1/4$; and pig supplier, $1/4$. Another method of dividing the returns among these three functions is: Producer, \$2 per head marketed; feed dealer, $1/2$ of profit; pig supplier, $1/2$ of profit.

REFERENCES

1. Anon: "Hog Industry May Be On The Verge Of Significant Change", Feedstuffs, January 3, 1970, p. 36.
2. Farris, P. L., "Alternative Coordination Policies", Economic and Marketing Information, Purdue University, Department of Agricultural Economics, October 31, 1969.
3. Rutter, James, "Get Ready to Join the 'System'," Doane's Agricultural Report, January 1, 1970, p. 4.
4. Candler, W. V., "Proposed Hog Industry Sub-Sector Research Program", Mimeo, Purdue University, July, 1969.
5. Crom, Richard J., and Wilbur R. Maki, "Evaluation of Alternative Market Organizations in a Simulated Livestock-Meat Economy", Iowa State University Research Bulletin 541, October, 1965.
6. Farris, Paul L., "The Aggregate Impact of Trends in the Farm Firm on the Economy and on Agriculture as an Industry", paper delivered at NCR-6 Seminar on Emerging and Projected Trends Likely to Influence the Structure of Midwest Agriculture, 1970-1985, Chicago, Illinois, November 12, 1969.
7. Stevenson, Jim and Norton Smith, "Will the Meat-type Hog Pays Its Way?" Economic and Marketing Information for Indiana Farmers, June 27, 1958.
8. "Meat Marketing - Trends and Practices", Food Topics, January, 1969, p. 45.
9. Gerstner, John, "Feed Hogs to 300 Pounds?", Farm Journal, December, 1969, p. 5.
10. O'Bryant, J. B., "Serious Information Gap: Here's How the Price of Live Hogs is Determined", The National Provisioner, August 17, 1968.
11. Kadlec, J. E. and W. H. M. Morris, "How Big Should the Swine Enterprise Be", Journal No. 22, Ag. Exp. Station, Purdue University, Lafayette, Indiana, 1966.
12. Kadlec, J. E., et. al., Comparison of Swine Growing-Finishing Building Systems, No. 816, Purdue University Agricultural Exp. Station, Lafayette, Indiana, August, 1966.
13. Daniel, R., et. al., Productivity and Cost of Swine Farrowing and Nursery Systems, Res. Progress Report 315, Sept., 1967, Purdue University Agricultural Exp. Station, Lafayette, Indiana, p. 8.

14. Hadley, N. S., "Evaluating the Potential Success of Investment in Future Swine Systems", paper presented at Indiana Bankers' Agricultural Clinic, March 16 and 17, 1967, Purdue University, Lafayette, Indiana.
15. Morris, W. H. M., "Economics of Liquid-Manure Disposal from Confined Livestock", Management of Farm Wastes, (Proceedings National Symposium, May 5, 6, and 7, 1966, pp. 126,127,128,129,130,131). Published by American Society of Agricultural Engineers, St. Joseph, Michigan.
16. Bauman, R. H., "Comparative Costs of Portable and Permanent Structures in Swine Production and the Effect of Intensity of Use on Costs", Mimeo EC-149, July, 1957, Dept. of Ag. Econ., Purdue University.
17. Anon., "Now - A Mobile Hog for Pigs", Successful Farming, Sept., 1968.
18. Snyder, J. C., Larry L. Nelson and Thomas Guthrie, "Profit Planning and Control, A Computer Oriented System For Feed Industry Management", Purdue University, January, 1969.
19. Peele, Olin, "Designing the Ideal Marketing System", Proceedings from 11th National Pork Industry Conference, Raleigh, North Carolina, December 12-13, 1968.
20. Feedstuffs, February 21, 1970, p. 10.
21. The Tend-R-Leen Swine Program, Ind. Farm Bureau Coop. and Producers Marketing Association.
22. The Story of Kleen-Leen Inc., Liberty, Ind. and Cedar Rapids, Iowa.
23. Homemakers' Opinions About Selected Meats, A Nationwide Survey, Marketing Research Report No. 854, USDA and National Livestock and Meat Board, July, 1969.
24. Gaarder, R. O. and E. A. Kline, "What Kind of Ham Do People Want?", Iowa Farm Science, March, 1958, pp. 9-10.
25. Naumann, H. D., et. al., A Large Merchandising Experiment With Selected Lean Pork Cuts, Mo. Res. Bul. No. 711.
26. Stevenson, Jim and Norton Smith, "Will the Meat-type Hog Pay Its Way?", Economic and Marketing Information for Indiana Farmers, June 27, 1958.
27. Jenny, Wilbur, "Coordination in the Swine Industry", [38, Chap. 21].
28. Rieth, James N., "A Dynamic Synthesis of Tactual and Strategy Formulation: An Industrial Application," Unpublished Ph.D. Dissertation, Purdue University, Dept. of Ag. Econ., June 1970.
29. Nelson, Larry L., "Implementation of Large Scale Planning Systems: A Study of Computational Dynamics and Managerial Interface", Ph.D. published Dissertation, Purdue University, Dept. of Ag. Econ., June 1971.

30. Guthrie, Thomas L., "Initial Forward Planning Strategy and Successive Review by the Commercial Feed Firm Utilizing a Static Compacted Linear Programming Model", Unpublished Ph.D. Dissertation, Purdue University, Dept. of Ag. Econ., June 1970.
31. Al. Mueller, pers. com.
32. "Economies of Size and Economic Efficiency in the Hog Enterprise", Research Bulletin No. 699, Dept. of Ag. Econ., Purdue University.
33. Hadley, N. S., "What Makes the Difference in Farm Earnings?", Economic and Marketing Information, Purdue University, Dept. of Ag. Econ., Dec. 31, 1969.
34. Armstrong, J. H., and R. E. Schneidau, "Coordinated Hog Production and Marketing", EC-313, Sept., 1967, Cooperative Ext. Service, Purdue University, Lafayette, Indiana.
35. Schroder, William R., "Application of Systems Models to the Analysis of Selected Swine Management Decisions", unpublished Ph.D. Thesis, Purdue University, 1968.
36. Matthes, Robert, A Management Information and Control System for Hog Fabrication. Unpublished Ph.D. Thesis, Purdue University, Aug., 1967.
37. Supermarket Institute, SMI Meat System for Computer Operations, Chicago, Illinois, 1967.
38. Snyder, James C., "Programmed Profit Analysis for Hog Fabrication", Mimeo, Department of Agricultural Economics, Purdue University.