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IDENTIFICATION AND AN L.P. ANALYSIS OF ALTERNATIVE PLANS FOR DAIRY FARM ADJUSTMENT IN SOUTH-EASTERN MINNESOTA[1]

by

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* Helming was a visiting scholar working with Earl Fuller in the Department of Agricultural and Applied Economics during the period within which the paper was written.

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CHAPTER 1: INTRODUCTION

1.1 The Dairy Sector In The Upper Midwest

1.1.1 Introduction

Minnesota is part of the U.S. Upper Midwest. In dairy terms this region consists primarily of Minnesota and Wisconsin. This section provides a short overview of the development and today's structure of the dairy sector in the Upper Midwest. Comparisons to other regions are made. Special attention is given to the dairy sector in Minnesota.

U.S. milk production increased from 124.2 billion pounds in 1965 to 145.4 billion pounds in 1988, a 17 percent increase. The Upper Midwest region is the dominant milk producing region in the U.S. The Upper Midwest provided 24.6 percent of the milk produced in the U.S. in 1988. On a state by state basis Wisconsin ranked first with a total milk production of 25,000 millions pounds in 1988. Minnesota was fourth with a total milk production of 10,400 million pounds.

1.1.2 Productivity And Herd Size

A considerable decline in the number of dairy farms in the Upper Midwest occurred between 1970 and 1987. The number of dairy farms in Minnesota decreased by 63 percent. There were 46,000 dairy farms in 1970. There are 17,000 in 1988. During the same period herd size increased by 74 percent. It went from 25.7 cows in 1970 to 44.8 cows in 1987. The average herd size of all dairy producing farms in the U.S. in 1987 was 49.9.

During the 1970 to 1988 period, milk production per cow increased by 40 percent in the Upper Midwest. It went from 9,935 pounds per cow in 1970 to 13,926 pounds in 1988. In 1988 average milk production per cow in the U.S. was 14,145 pounds. On a state by state basis, Wisconsin ranked eighteenth (14,205 pounds per cow) and Minnesota ranked twenty-ninth (13,299 pounds per cow).

Lower average milk production per cow generally has a two fold effect on profitability; less milk marketed and higher average total cost of production per unit. Studies indicate that typical returns to labor and management increase $0.25 to $0.40 per cwt of milk for each additional 1,000 lbs of milk produced per cow. Milk and feed prices will affect this value (Conlin, 1990).

Dairy farms with milk cows in the Upper Midwest are significantly smaller than in most other regions. The latest Agricultural Census shows that in 1987, 83 percent of all farms with milk cows in the Upper Midwest had more than 20 and less than 99 cows and 5.0 percent had more than 100 cows. The U.S. totals shows that 57.4 percent of all farms with milk cows had more than 20 and fewer than 99 cows and that 10.1 percent of all farms with milk cows had more than 100 cows.

The same conclusion can be drawn by a study of Stanton and Bertelsen in 1989. They analyzed dairy farm costs and returns selected from the 1987 U.S. Farm Costs and Returns Survey (FCRS). Specialized dairy farms were defined from that basic sample as those were 50 percent or more of total commodity sales came from milk. Classification of these specialized dairy farms is based on the value of milk sales per farm. The U.S. is divided into six regions. Some of the results are shown in Table 1.1. They found that in the Lake States Region, defined as Minnesota, Wisconsin and Michigan, 46.5 percent of all farms had a value of milk sales from $60,000 to $149,999.

For the total U.S. this percentage was 41.6. They also stated that 7.6 percent of the specialized dairy farms in the Lake States had a value of milk sales in excess of $150,000 against 17.3 percent in the U.S. (Stanton and Bertelsen, 1989).

Table 1.1: Percentage of specialized dairy farms divided by milk sales, 1987.

	Less than $60,000	$60,000- $149,999	More than $150.000
		Percentage	
Lake States	46.8	46.5	6.7
U.S.	41.1	41.6	17.3

Source: Stanton and Bertelsen, 1989.

Economies in capital use on dairy farms results in higher investment costs per unit of output on farms with a smaller size of operation. A study by Stanton showed a decrease in total cost per cow of 55 percent, from $2,281 to $1,029, when herd size increases from 50 cow herds to 250 cow herds. He assumed that a herringbone double 4 milking system is used with minimal mechanization and that the efficiency of the workers doesn't decrease (Stanton, 1980). A more recent study in the University of Minnesota, shows that the estimated minimum milk price needed to cover all costs associated to investments in new facilities ranges from $12.68 per cwt for 40 cows to $10.51 for 120 cows in tie stall barns. The break-even prices for new free stall barns were $11.07 for 50 cows to $9.03 per cwt for 200 cows (Conlin, 1990 using unpublished data by Dornbush 1988).

1.1.3 Investment Level

The average investment costs per cow on dairy farms in the Lake State Region was $6,712 per cow on January 1, 1988. In the U.S. total, the average investment costs per cow on dairy farms was at that time, $6,481 (U.S. Department of Commerce, November 1989 and U.S. Department of Agriculture, USDA, April 1989).

The larger investment costs per cow in the Lake States is due in part to the production of most or all of their feed requirements. Combination of cropping enterprises with the dairy enterprise are the norm. As a result dairy farming in the Upper Midwest is capital intensive, requiring equipment and facilities for both crop and milk production (Jeffrey, 1988). Climate also explains some of the differences in housing investment as does differences in perceived needs in milking facilities, forage storage, land holdings, cropping investment and size of the operations.

Farms, producing a major portion of the feed for the dairy herd, are diversified in the capital investment, labor activities and management expertise required. Table 1.2 shows a typical investment for various levels of diversification for a 50 cow dairy farm. Raising only forages and purchasing grains reduces the land and field machinery investments needed by 20-30% compared to raising all feeds. Some studies indicate that this option to be fairly low risk and usually more profitable than raising all feed (Conlin, 1990).

Table 1.2: Per cow investment capital for diversified and specialized farms.

	Produce all feed	Produce forage only	Purchase
Acres per cow	4.5	3.0	1.0
Dairy animals	1,500	1,500	1,500
Dairy building and equipment	1,100	1,100	1,100
Land ($800 acre)	3,600	2,400	800
Crop machinery	1,260	640	340
Inventory/working capital	300	300	300
Total investment/cow	7,760	5,940	4,040

Source: Conlin, 1990

1.1.4 Debt Level

As a result of the decline in asset values and increased real interest rates in the beginning of the eighties, many of the capital intensive Upper Midwestern dairy farms found themselves in a precarious financial situation. Ahearn, Dubman and Henson estimate that in 1985 the average leverage ratio[2] for Upper Midwestern dairy farms was 0.667. The U.S. average leverage ratio for dairy farms was 0.37. (Jeffrey, 1988). More recent data shows a debt/asset ratio (D/A)[3] on dairy farms in the Lake States on January 1, 1989 of 0.21. At the same time the D/A ratio on all dairy farms in the U.S. was 0.20 (USDA, January 1990). The financial situation on the average dairy farm in the Lake States has significantly improved since the early eighties.

1.1.5 Milk Price

The price received for milk by Minnesota and Wisconsin farmers is lower than in most other regions. In 1987 the average price received for all milk was $12.06 per hundredweight in the Upper Midwest. In the U.S. as a whole the price received for all milk was $12.54 per hundredweight. This difference is largely due to two factors: the Upper Midwest is the major milk surplus region in the U.S., and much of the milk produced there is used for manufacturing purposes (Jeffrey, 1988). The difference in average milk price received by all dairy farms for all milk and for manufacturing grade milk was $1.17 in 1987 (USDA, May 1989).

1.1.6 Economic Performance

Recent Wisconsin and Minnesota studies identifies production per cow, herd size, debt level and capital investment as having a high correlation with a residually imputed labor and management return (Conlin, 1990). Table 1.3 compares dairy returns with variable,

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[2] The leverage ratio is a solvency measure. It indicates the farm's overall financial risk of the farm to the farmer and the lender. It shows the amount of debt relative to the net worth or owner's equity. It shows the amount of debt held by a farm for every dollar of equity (Olson, 1988).

$$\text{Leverage Ratio} = \frac{\text{Total Liabilities}}{\text{Total Equity}}$$

[3] The debt-to-asset ratio (D/A) is like the leverage ratio, a solvency measure. It measures the size of the farm's debt load relative to the total asset value. When expressed as a percentage, the debt to asset ratio quickly shows the extent to which the farm's assets are financed by debt capital versus equity capital (Olson, 1988).

$$D/A = \frac{\text{Total Liabilities}}{\text{Total assets}} \times 100$$

overhead and total costs for seven dairy regions studied by USDA in 1988. In this study the Upper Midwest consist of Michigan, Wisconsin, Minnesota and South Dakota. Table 1.3 shows that the lower cash costs in the Upper Midwest probably due to less purchased feed, can't offset the higher overhead costs and the lower total returns. The differences in the above mentioned factors between the Upper Midwest and the U.S. and the resulting difference in impacted returns to risk and management, might result in a further shift in milk production to the Northwest, Southwest and Southeast regions.

Table 1.3: Regional average costs and returns per cwt of milk, 1988.

Region	Total Returns	Cash Costs	Allocate Overhead Costs	Total Costs	Ret. Over Cash Costs	Ret. Over Full Costs
			$/Cwt.			
Upper Midwest	13.27	11.19	2.70	13.89	2.08	-0.62
Corn Belt	13.61	11.52	2.36	13.88	2.09	-0.27
North East	13.82	10.23	2.69	12.92	3.59	0.90
Southern Plains	14.48	11.87	1.64	13.51	2.61	0.97
Pacific	12.22	10.44	0.73	11.17	1.78	1.05
Appalachian	14.03	10.53	2.17	12.70	3.50	1.33
South East	16.14	13.34	1.14	14.48	2.80	1.66
U.S.	13.94	11.30	1.92	13.22	2.64	0.72

Source: Hoard's Dairyman, January 10, 1990 based upon USDA 1988 data.

1.1.7 <u>The Dairy Sector In Minnesota</u>

There has been a decline of Minnesota's share of U.S. milk production. Minnesota's share declined from its peak of 8.6 percent in 1965 to 7.0 percent in 1989. The total dairy herd in Minnesota declined from 1.1 million in 1967 to 723 thousand in 1989. That represents a decline of 34 percent. Minnesota's change in total dairy herd has essentially paralleled the national picture. The decline in Minnesota's share of U.S. milk production is explained by its lower increase in productivity per cow. For the U.S. the ten-years' increase in product from 1967 to 1977 was 27.1 percent. It went up another 23.3 percent for the period 1977 to 1987. Minnesota, production per cow was above the national average in 1967, it is now below the national average. Minnesota's performance is also some what less than average in the Upper Midwest. These state and national trends in milk production concern many leaders in Minnesota's dairy industry (Hammond, 1989).

1.2 Problem Statement And Definition

The problems indicated at the sector level are symptoms of comparative disadvantage problems at the farm level. Comparative disadvantage is not only determined by differences in physical factors such as soil, climate, topography, and distance to the market (which is reflected in transportation costs). Skillful management control of the factors affecting profitability is important. In an agriculture which is highly mechanized, uses many technological innovations and operates with large amounts of borrowed capital, management takes on a new (dimension and) importance. Luck cannot explain all the differences observed in the profitability of dairy farms between regions. Luck cannot explain the differences in the profitability among those in the same region, which have similar amounts of land and capital available. Farm business records from many states show the top one-third of the farms to be highly profitable while the bottom one-third are often operated at a loss.

Differences in management can show up in three areas: production, marketing and financing (Kay, 1986). Kay uses a definition of farm management which says: "Farm management is the decision-making process whereby limited resources are allocated to a number of production alternatives to organize and operate the business in such a way as to attain some objective(s)" (Kay, 1986). The process of making a decision can be formalized into a logical and orderly series of steps. Important steps in the decision making process are:

- setting goals;
- identify and define the problem and opportunities;
- collect relevant data, facts, and information;
- identify and analyze alternative solutions;
- make the decision-select the best alternative;
- implement the decision;
- evaluate the results, bear responsibility for the outcome and learn (Kay, 1986 and Castle, et al, 1987).

Management functions are planning, implementation and control. Planning is the most basic management function. It is primarily making choices and decisions: selecting the most satisfying alternative from among all possible alternatives.

Davis and Olson distinguishes between different planning levels. They call planning for five years and more the strategic plan. In general it concerns production decisions and selections of supporting enterprises to include in the business, the way they want to finance each enterprise, and the amount of resources to be devoted to each enterprise. A modern dairy producer's strategic plan concerns his investments in land and capital. Important planning areas to be considered are:

- location of the facility;
- size of the planned herd;
- source and amount of money available;

- amount of labor available;
- kind of housing system to be used;
- kind of milking system to be used;
- degree of mechanization of milking system;
- feed handling system;
- degree of mechanization of cropping enterprise.

These decisions affect the ability to compete with other producers locally and in other regions. Once a strategic plan is in place it is often several years before it can be altered to a significant extent.

Davis and Olson refer to the plan for the next year as the tactical plan, and the plan for this year is called the operational plan. Tactical plans have their influence on the manager's objectives for the next five years. On a dairy farm it concerns decisions about future cropping programs, marginal additional land and capital investments, herd breeding programs, health of the dairy herd, and the marketing of the products. Operational plans have their influence on the farms objectives in this year. In general, it concerns decisions about the use of managerial inputs of all kind.

In this paper we suppose that farm management is concerned with the decisions that affect the profitability of the farm. A goal of most dairy producers is to at least increase profits. This study will analyze the noted differences in profitability due to differences in production management on a model dairy farm in South Eastern Minnesota. For that purpose a set of, more or less, strategic plans as Davis Olsen defines them are first identified and then analyzed.

1.3 Methodology

The farm planning problem is how, in uncertain biological and economic environment, to allocate the available resources to the various activities in order to best achieve the farmer's objectives. Dent, et. al. state that the linear programming technique can be applied to planning problems with the following characteristics:

- a range of activities are possible and the farm manager can exercise a choice in the selection of activities that he wishes to put into operation;
- various constraints prevent free selection from the range of activities;
- a rational choice of a combination of activity levels is related to some measure of the manager's utility associated with each of the activities, that is, there is an objective which can be quantified.

For complex planning problems, linear programming (LP) can be used to find a "best" plan. The LP procedure improves the accuracy of the analysis (Kay, 1986). In this paper a LP model is used to determine the impact of various combinations of activities on the profitability of an average farm. The LP model used, analyzes operational or short-term plans. The objective function of this model consists of cash receipts and cash expenses. This means that land and capital available to the farmer must be valued outside the LP analysis. To determine the profitability of an alternative strategic plan, the maximum gross margin (cash receipts less cash expenses) is adjusted for the annual overhead costs of that particular plan.

1.4 Overview Of The Other Chapters

In Chapter 2 we give a short discussion of the various plausible activities and limited resources and other constraints in the model. The data input needed to represent a dairy farm is described. The specific characteristics of the model dairy farm is also presented in Chapter 2. In Chapter 3 we discuss the alternative strategic plans to be analyzed and the profitability of each plan. Chapter 4 is a discussion of the assumptions incorporated in LP models. We also discuss a few important assumptions concerning input data used. Chapter 5 offers the summary and conclusions.

CHAPTER 2: DESCRIPTION OF THE LP MODEL AND INPUT DATA

2.1 Introduction

The basic model used in this paper was developed by Dornbush. He used SMALLP to determine the optimal combination of activities on dairy farms of different herd sizes considering different capital investments. The model was focused on two goals. One was to project the average cost per unit of output or profit that firms of various sizes could potentially achieve using various modern or advanced technologies. The second goal was to find the differences in average cost per unit of output attributable to differences in size. An extensive description of the LP model can be found in his thesis (Dornbush, 1989). An overview of the slightly modified and reduced Dornbush model used in this study and a description of the input data used is included.

2.2 Overview Of The LP Model

The column (activities) of the model represent the livestock and crop production alternatives available for consideration. The last column (the right hand side) specifies the amount of resources or level of constraints. For example, tillable acres and hours of operator and family labor available are right hand side specifications.

The level of a given activity in the model is determined subject to the resource constraints applicable to the activity. Constraints include land, labor and feed and fertilizer needs and various intermediate product accounting control. The last row is the objective function. In this case it specifies the per unit vector gross margin for each activity. Each of the activities has one of two effects on gross margins; it adds to the gross margins of the farm (sale of milk), or it represents a cash expense to the farm but also permit another activity to occur which adds to total gross margins (hiring labor, growing crops or milking cows).

In algebraic terms:

SMALLP maximizes:

$$z = \Sigma\, c_j x_j \qquad \text{for } j = 1,\ldots\ldots,N$$

subject to

$$\Sigma\, a_{ij} x_{ij} \leq b_i \qquad \text{for } i = 1,\ldots\ldots,M$$

and $b_i \geq 0$

$x_{ij} \geq 0$

Column activities in the model are grouped in the following numerical order (C1 to C83): livestock production, C1-C2; crop production, C3-C16; crop harvesting and storage, C17-C39; livestock feeding, C40-58; purchasing inputs, C59-C74; sale of output, C75-C82; and fixed overhead accounts C83. The right hand side specifications are in C84.

Constraints rows (R1 to R56) are grouped in a similar fashion: physical livestock constraints, R1-R6; livestock nutritional constraints, R7-R12; land controls, R13-R18; fertility constraints, R19-R21; crop harvesting controls, R22-R31; stored crop controls, R32-R34; feeding controls, R36-R44; labor controls, R45-R50; field time controls, R51-R55; and forced control of fixed account, R56. The per unit vector gross margins or the objective function, is in R57. Tables A1 and A2 in Appendix A offer a description, including units, of each column and row in the LP matrix.

Mghizou states that if we view the farm enterprise as a system, the primary focus would be on the distinction of the main subsystems. This distinction is based on the management strategy each of the subsystems requires in order to achieve the overall system objectives (Mghizou, 1985). In Dornbush's model the dairy enterprise is seen as a system consisting of three subsystems:

1. dairy enterprises (a profit center);
2. crops enterprises;
3. support services or cost centers.

The dairy enterprise subsystem is a production process that requires resources in order to produce milk, calves and manure. Raising replacements are modeled outside the dairy subsystem. The resources required for raising replacements are used for producing replacement heifers and manure. Heifers are transferred to the dairy subsystem once they start milking.

The cropping enterprise is a production process that requires resources in order to produce crops. It consists of all activities with respect to the stages of planting, harvesting, storage and feeding or the sale of the crop. These stages are linked to each other. The linking coefficients account for harvesting and storage losses. Crop production activities are desegregated to accurately reflect differences between various methods of growing, harvesting and storing crops. For example, growing ear corn on last years' corn ground provides a lower yield and requires more nitrogen than if ear corn is grown on soybean or alfalfa ground. Harvesting losses are lower for high moisture ear corn than for dry ear corn. Storage losses, labor and field time requirements are different when high moisture ear corn is stored in horizontal silos than when its stored in upright silos. The cropping enterprises is linked to the dairy enterprises by the transfer of crop products to animal feeding activities, including feeding losses and by the use of animal manure as an input to crop production.

The supporting service or cost centers component of the firm are made up of assets which service the other enterprises. In accounting terms they are required if the business exists. They are costed as time related overheads unrelated to enterprise level or size. These assets do not provide returns directly. Supporting service assets include overhead type labor for general farm upkeep, buildings, machinery and land. Machinery provided to the crops enterprise and milking facilities provided to the dairy enterprise are examples of the interrelationships in use which exist. The dairy and crop profit centers provide funds for replacement of supporting service center resources as they become worn out or obsolete (Dornbush, 1989).

2.3 The Data Input

Dornbush sees the dairy farm as a system divided in three subsystems. An extensive description of the data input of the three different subsystems can be found in his thesis (Dornbush, 1989). He also gives a detailed specification of the assumptions which underlie each subsystem. Tables 2.1, 2.2 and 2.3 offer the data input required to model the three subsystems.

Table 2.1: The Dairy Enterprise.

Area:	Sub area:	Data input:[4]
A: Production	1. Milk cows	a. Calving interval: - days in milk; - dry period. b. Milk production per cow. c. Percentage butter fat. d. Body weight. e. Annual replacement rate: - culling rate; - mortality. f. calf crop: - percentage calving; - calf death losses.
	2. Replacements	a. Age of heifers freshening b. Number of raised animals available for cow replacement: - death losses; - non breeders selection; - culling selection.

[4] Some data such as animal replacement rates, animal death losses and feeding losses are implied by the coefficients linking column activities.

Table 2.1 continued

	3. Bedding	a. Bedding needs for cows: b. Bedding needs for heifers.
	4. Manure	a. Purchased fertilizer: - fertility needs in crop enterprises - manure nutrients produced by cows; - manure nutrients produced by heifers.
B: Nutrition		a. Nutrient requirements and dry matter intake cows: - production level; - body weight; - fat production. b. Nutrient requirements and dry matter intake heifers: - growth per day. c. Feeding losses.
C: Labor Requirements		a. For the milking herd: - type of milking facility; - level of mechanization in the milk facility; - level of production; - milking routine; - time period; - etc. b. For raising heifers.
D: Gross Margins		a. Cows: - cash receipts; - cash expenses. b. For raising heifers: - cash receipts; - cash expenses.

Table 2.2: Major Considerations in the Cropping Enterprise.

Area:	Sub area:	Input data required:[5]
A: Crop production		a. Gross margins: - cash receipts; - cash expenses. b. Labor requirements for field operations. c. Field time available.
B: Harvesting and storage	Harvesting methods	a. Gross margins: - cash receipts; - cash expenses. b. Labor requirements. c. Harvesting losses: - crop harvested; - machinery adjustment; - moisture content.
	Storage methods	a. Gross margins: - cash receipts; - cash expenses. b. Labor requirements. c. Storage losses: - crop type; - moisture content; - structural condition of forage facility.
C: Sales and Purchase	Sales Purchase	a. Product prices b. Input prices

[5] Some data such as harvesting and storage losses are implied by the coefficients linking column activities.

Table 2.3: Support Cost Center Considerations

Area:	Data input:
A: Full-time labor	a. Work time b. Family drawing amounts
B: Land	a. Tillable acres b. Acres suitable for corn or alfalfa c. Acres possible devoted to row crops d. Acres in permanent pasture e. Land ownership changes
C: Facilities	a. Herd size:[6] - labor available for milking; - throughput; - milking facility; - production level. b. Investment costs
D: Livestock	a. Production capability b. Investment requirements
E: Machinery	a. Cropping program consideration
F: Annual overhead charges	a. Annual overhead expenses for: - labor; - land; - structures; - machinery; - Livestock.

2.4 Characteristics Of The Basic Model Farm

The model dairy farm analyzed here, is a two family farm capable of milking 100 head producing 18,000 pounds of milk per cow per year in a free stall facility. The milking facility consists of a double 8 herringbone with automatic detachers, crowd gate and feed bowl covers (full mechanization). The model may choose between upright and horizontal silage storage structures. The dairy farm is 183 acres in size. It has 160 tillable acres and 137 acres suitable for corn or alfalfa production. A maximum of 76 acres may be devoted to row crops. Twenty-three acres is in permanent pasture.

The next Chapter discusses the results of an L.P. analysis of this basic model with several sets of technologies in use.

6 The facilities needed is determined by the size of the herd.

CHAPTER 3: RESULTS

3.1 Introduction

An important step in the decision making process is the identification of alternative plans. This step can be taken after the manager's goals and concerns are known and after the relevant information has become available. The analysis of each alternative plan should occur in a logical and organized manner to ensure accuracy and to prevent something from being overlooked (Kay, 1986).

In this Chapter an identification of feasible alternative plans for the model conditions are presented. The second part of this chapter offers a comparative analysis of profitability, in terms of required milk price to cover all economic costs, for the alternative plans.

3.2 Identification Of Alternative Plans

A first run of the model established a basic plan. The cropping program consisted of 9 acres of corn silage in a corn on corn rotation, 46 acres of corn silage and soybeans in a corn on soybean rotation, 21 acres of corn silage on 21 acres of last year's alfalfa ground, 21 acres of alfalfa with a companion crop of oats which is harvested as oat silage and 63 acres of alfalfa providing 4.5 dry matter tons per acre of alfalfa per year in three cuttings. The soybeans are sold as a cash crop.

The model chooses between technologies such as upright and horizontal silos while ignoring overhead cost differences. A large round baler is used to harvest second and third cutting alfalfa hay. Upright silos were used for storaging corn silage and oat silage. Hay silage is stored in a horizontal silo and alfalfa hay is stored in a hay shed. Additional purchased feedstuffs are stored in grain bins. The farm raises its replacements. Straw is purchased to meet the livestocks' bedding needs.

The basic plan uses upright silos. In plan 2 a limitation is placed on the use of upright silos.

Two alfalfa hay harvest systems are compared. In the basic plan the farm uses a large round baler to harvest second and third cutting of alfalfa. In plan 3 a square (conventional) baler is used.

In the base plan the farm increases gross margin by selling soybeans. In plan 4 the farm isn't allowed to sell soybeans. Due to the high investment costs in crop machinery, the farm is not allowed to grow ear corn and high moisture shelled corn, in plan 4.

In the base plan the farm buys all bedding. In plan 5 the farm must raise its bedding. The use of corn stalks as bedding is limited due to high machinery investment costs.

The farm raises replacement heifers in the base plan. Based on a discussion in the November 1989 issue of Dairy Herd Management, a sixth alternative is analyzed in which the farm must buy replacements. Constraints are also set on the use of corn stalks as bedding and on the storage of oats grain and oats silage.

Table 3.1: Production in dry matter tons of feed crops by plan

	Basic Plan	Alternative plans		
		Plan 4	Plan 5	Plan 6
Corn silage (DMT)*	491.6	570.3	476.7	491.6
Oatlage (DMT)	37.5	32.2	-	-
Oats for grain (DMT)	-	-	11.3	4.2
1st Cut Alfalfa (DMT)	151.6	130.2	65.7	151.6
2nd & 3rd Cutting (DMT)	199.6	171.5	68.4	157.9
Total (DMT)	880.3	904.2	627.7	810.9

* DMT - Dry matter tons

3.3 Analysis Of Alternative Plans

3.2.1 Introduction

This section contains the results of the model experiments in 3.1. Table 3.1 presents the production in dry matter tons of the cropping program section. The cropping programs and therefore the dry matter yields in the basic plan, plan 2 and plan 3 are the same.

Table 3.3 gives the gross margins (cash receipts less cash expenses) of the alternative plans. Table 3.4 presents the minimum milk price required to cover all costs (including annualized investment costs) plus other overhead charges for the alternative plans. The relative profitability of each plan is suggested by the "minimum milk price required to cover all costs". This price is calculated by adding back the milk sales to the LP gross margin and then deducting the annual imputed investment and labor charges. The result is divided by the milk volume.

Table 3.4 shows that the required milk price to cover all costs of plan 2, 3 and 4 are lower than it is for the basic plan. It shows that compared to plan 2, 3 and 4 the higher gross margins in the basic plan is not enough to offset the higher annual overhead costs. Plans 5 and 6 offer lower long run profitability opportunities for the model farm. In all cases, the resulting milk price is above expected long range price projections.

3.2.2 Horizontal Silos Versus Upright Silos

The basic model uses two concrete upright silos for the storage of corn silage. Each upright silo is equipped with a silo unloader. In plan 2 the farm is limited to horizontal silos. This causes no shifts in feed production.

Corn silage is harvested at a higher moisture content for storage in the horizontal silo. This results in lower harvest losses than when silage is stored in upright silos at a lower moisture content. Storage losses do make a difference. Table 3.2 shows cumulative percent dry matter retained from standing crop through feeding for the various crops and storage methods available in the model. Storage of corn silage in an horizontal silos results in a reduction of Dry Matter retained from the standing crop to feeding of 6.5 percent. Data was not available to clarify the relationship between silo volume and accumulated losses.

Table 3.3 shows lower cash expenses for corn silage in Plan 2. This is caused by lower cash expenses for storage of corn silage in horizontal silos. Since storage losses in horizontal silos is greater, additional feed has to be purchased to meet the feed requirements of the cows and the replacements. Additional ear corn is purchased and fed to the cows to compensate for these losses in corn silage. Additional soybean meal is purchased and fed to the replacement to meet the feed requirements for the replacements. These higher costs for purchased feed stuffs offsets the lower storage costs for corn silage in plan 2 (Table 3.3).

Table 3.2: Cumulative percent Dry Matter retained from standing crop to feeding by crop, harvest method and storage method.

	CROP				
Harvest and Storage Method	HMSC	Corn Silage	Alfalfa Hay	Alfalfa Haylage	Oat Silage
			% Retained		
Upright Silo	81.9	86.0	-	79.4	79.4
Horizontal Silo	75.7	79.5	-	75.8	75.8
Square Bale - Inside	-	-	74.5	-	-
Large Round Bale - Inside	-	-	69.1	-	-

Source: Dornbush, 1989.

Table 3.3 shows that plan 2 results in additional costs compared with the basic plan, more additional labor is hired in the September 1 to October 15 period and less in the April 1 to May 15 period.

The gross margin in the basic plan is $2,122 higher. Table 3.4 shows that due to lower investment costs in feed storage structures, the annual overhead costs is $7,129 lower in plan 2. With the same milk production, the required milk price to cover all costs in plan 2 is lower. Using horizontal silos reduces the minimum price $0.28 per hundred weight. On a whole farm unit it results in $4,941 additional economic income over using uprights.

3.2.3 Large Round Baler Versus Square Baler

Using a square baler for harvesting second or third cutting alfalfa hay, results in lower harvesting losses (Table 3.2), but cash expenses and labor are higher (Table 3.3). Consequently, the farm harvests less second or third cutting alfalfa as hay and more as haylage. More haylage also contributes to the decline in feeding losses in plan 3. Compared to the basic plan, less purchased feed is necessary to meet the feed requirements of the cows and replacements.

In plan 3, oatlage is also stored in a horizontal silo. This results in less cash expenses for the oatlage than in the base plan (Table 3.3). But as is shown in Table 3.2, using a horizontal silo for storage of oatlage results in more storage losses. In this case it appears to be cheaper to store the oatlage in a horizontal silo and buy some additional feedstuffs to compensate for the losses than to store the oatlage in a upright silo with less losses. However, the loss data used is not adjusted for silage volume.

Table 3.4 shows that even with the lower gross margin of plan 3, the required milk price to cover all costs is lower than in the basic plan. The lower investment costs in feed storage structures and machinery and the resulting lower annual overhead costs offsets the lower gross margins. In comparison to the basic plan the required milk price to cover all costs is $016 lower per hundred weight. It results in $2,824 additional income over using a large round baler.

3.2.4 Cash Crops Versus Feed Crop Production

Producing and marketing cash crops is a separate enterprise on the dairy farm. It competes for resources with the dairy enterprise. In the basic plan the farm generates a part of the cash receipts by selling soybeans. Plan 4 disallows soybean production. This changes the farm's feed production and use. The cropping program consists of 36 acres of corn silage in a corn on corn rotation, 22 acres of corn silage and soybeans in a corn on soybeans rotation, 18 acres of corn silage on 18 acres of last year's alfalfa ground, 18 acres of alfalfa with a companion crop of oats which is harvested as oat silage and 54 acres of alfalfa providing 4.5 dry matter tons of alfalfa per year in three cuttings. The dry matter production of the cropping program in plan 4 can be found in Table 3.1. The farm increases the production of corn silage. The production of corn silage increases to 570.3 dry matter tons (Table 3.1). At the assumed levels of feed requirement the purchase of additional feed stuffs is no longer necessary (Table 3.3).

Table 3.3 shows a gross margin in plan 4 that is $1,239 lower than the basic plan. Table 3.4 shows that plan 4 generates some additional income from land rented out because it is not needed to maintain a feed balance. When we include the rent on the land rented out, the gross margin is only $471 lower. The minimum milk price to cover all cost in plan 4 is slightly less. This is due to the lower investment costs in feed storage structures. The minimum milk price to cover all imputed overhead costs is $14.59 (Table 3.4). Compared to the basic plan, this is a reduction of $0.06 per cwt. Eliminating soybeans would result in $1,059 additional economic income over selling soybeans.

3.2.5 Raising Own Bedding

In the original model the farm's bedding needs may be met by utilizing the farm's crop residues (straw and corn stalks), by purchasing straw or a combination of these two activities. In the basic plan the farm purchases straw to meet bedding needs. In plan 5 we analyze the effects of raising bedding instead. An additional constraint is set on baling and using corn stalks, because of the high additional investment costs in machinery. The farm produces oats grain and uses the straw as bedding.

The farms' crop plan consists of 21 acres of corn silage in a corn on corn rotation, 46 acres of corn silage and soybeans in a corn on soybean rotation, 9 acres of corn silage on 9 acres of last year's alfalfa ground, 57 acres of alfalfa with a companion crop of oats which is harvested as grain and 27 acres of alfalfa providing 4.5 dry matter tons of alfalfa per year in three cuttings. The total dry matter yield can be found in Table 3.1. The production of oat grain reduces the production possibilities of alfalfa. From Table 3.1 we can see that the total yield of the cropping program in plan 5 is 258,2 dry matter tons less than the cropping program in the basic plan. Table 3.3 shows that the cash expenses of the forages are almost $2,600 higher. In plan 5 much more purchased ear corn and soybean meal is necessary to meet the cows and replacements feed requirements. The difference in purchased feed between the basic plan and plan 5 is almost $9,700 (Table 3.3). Due to this the gross margin of plan 5 is, compared to the basic plan, $8,281 lower.

The lower annual overhead cost for feed storage structures is partly offset by the higher annual overhead costs for machinery in plan 5 (Table 3.4). Compared to the basic plan, the slightly lower overhead costs in plan 5 can't offset the lower gross margin. The resulting minimum milk price to cover all costs increases to $15.06. This is an increase of $0.41. Raising all bedding results, in this case, in a reduction in farm income of $7,233.

3.2.6 Heifers: Raise Or Buy

A discussion in the November 1989 issue of Dairy Herd Management points out that there are three options available to producers for replacement stock: raise heifers, contract someone who specializes in raising them, or buying replacements.

In the basic plan the farm raises replacements. This can be viewed as a separate enterprise in the dairy enterprise. This means that it computes for labor time and capital with managing the dairy. In the basic plan the replacement animals account for almost 14 percent of total cash expenses. In plan 6 analyze the effects of buying replacements for our farm. The dairy farm buys his replacements at $850 a head. They come into the milking string right away. Additional constraints are set on baling and using corn stalks, producing oats silage, and on the storage of oats grain.

In the basic model the farm uses the 23 acres of non-tillable pasture only for feeding the replacements. Buying replacements means that the acres of pasture are no longer needed. The cropping program consists of 9 acres of corn silage in a corn on corn rotation, 46 acres of corn silage and soybeans in a corn on soybean rotation, 21 acres of corn silage on 21 acres of last year's alfalfa ground, 21 acres of alfalfa with a companion crop of oats which is harvested as grain and 63 acres of alfalfa providing 4.5 dry matter tons of alfalfa per year in three cuttings. From Table 3.3 we can see that some additional purchased earcorn is necessary to meet the feeding requirements of the cows. The total gross margin is, compared to the basic plan, $8,282 lower.

Buying all the replacements results in a significant reduction of the overhead costs (Table 3.4). The farm generates some additional income by renting out pasture. Table 3.4 shows that the lower overhead costs can't offset the much lower gross margin. The resulting minimum milk price to cover all costs is $0.30 higher compared to the basic plan. Buying all his replacements instead of raising them results in $5,294 reduction in farm income.

Table 3.3: Gross margins (cash receipts - cash expenses) of alternative plans.

	Quantity	Basic Plan	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
			Alternative Plans Values				
				Dollars			
Cash Receipts							
Milk sold (cwt)	17,647	176,470	176,470	176,470	176,470	176,470	176,470
Bull calves sold (hd)	44	2,640	2,640	2,640	2,640	2,640	2,640
Heifer calves sold (hd)	44	-	-	-	-	-	4,400
Replacements sold (hd)	5	4,000	4,000	4,000	4,000	4,000	-
Soybeans sold (bu)	1,035	5,123	5,123	5,123	-	5,123	5,123
Oats grain sold (bu)	667	-	-	-	-	-	1,133
Total cash receipts		188,233	188,233	188,233	183,110	188,233	189,767
Cash Expenses							
Cows[1]		11,270	11,270	11,270	11,270	11,270	11,270
Replacement heifers[2]		2,618	2,618	2,618	2,618	2,618	0
Replacements bought		0	0	0	0	0	24,650
Crop production:							
Corn silage[3]		5,820	5,591	5,820	6,994	5,768	5,820
Alfalfa hay + haylage[3]		2,953	2,953	4,347	2,484	837	1,933
Oatlage[3]		902	902	888	763	0	0
Oats grain		-	-	-	-	5,465	2,011
Pasture		115	115	115	115	115	0
Soybean		1,417.00	1,417.00	1,417.49	688.90	1,417.49	1,417.49
Purchased feed:							
Soybean meal		1,111	1,785	606	0	7,887	0
Ear corn		2,746	4,266	2,529	0	5,659	736
Bedding		3,964	3,964	3,964	3,964	0	1,096
Hired labor		1,206	1,363	1,288	1,337	1,367	0
Total cash expenses		34,125	36,247	34,880	30,241	42,407	48,934
Gross margin		154,107	151,985	153,352	152,868	145,826	140,832

1. Includes cull sales.
2. Includes sale of non-breeding animals and springing heifers.
3. Includes harvesting and storage cash expenses.

Table 3.4: Investment costs, required milk price to cover all costs for alternative plans.

	Annual charge rate[1]	Basic Plan	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
			Alternative Plans				
		DOLLARS					
Land	9.00	102,480	102,480	102,480	102,480	102,480	102,480
Milking facilities[2]	22.00	215,733	215,733	215,733	215,733	215,733	215,733
Calf & heifer facilities[2]	22.00	11,542	11,542	11,542	11,542	11,542	0
Feed storage[3]	22.00	105,920	73,513	98,623	99,124	93,760	89,385
Machinery	27.00	251,454	251,454	244,057	251,454	257,390	255,795
Machine storage	22.00	30,370	30,370	30,370	30,370	30,370	30,370
Tools & misc. equipment	27.00	15,000	15,000	15,000	15,000	15,000	15,000
Base cow cost	20.51	87,500	87,500	87,500	87,500	87,500	87,500
Incremental cow cost[3]	40.71	35,000	35,000	35,000	35,000	35,000	35,000
Young stock[4]	10.00	14,450	14,450	14,450	14,450	14,450	0
Operator labor	100.00	40,000	40,000	40,000	40,000	40,000	40,000
Total Investment costs		869,449	837,042	854,755	862,653	863,225	831,236
Total annual OH		236,148	229,019	232,545	234,653	235,075	229,693
Land rental income[5]		0	0	0	768	0	1,495
Firm gross margin		154,108	151,986	153,352	152,869	145,826	140,832
Cwt milk produced (Some, all)		17,647	17,647	17,647	17,647	17,647	17,647
Required milk price/cwt - to cover assumed level of overhead costs		14.65	14.37	14.49	14.59	15.06	14.95

1. Factors used to calculate annual overhead expenses from investment costs.
2. Investment costs for structures and milking equipment are based on the "facility" program. (Fuller, E.I, and Goettl, M.). "Facility presents investment costs as a simple linear equation with a fixed component and an incremental component. The incremental component reflects the marginal change in investment cost for each additional cow housed and milked.
3. Investment costs in upright silos and horizontal silos are based on the "facility" program.
4. Reflects the increase in cow value as its genetic potential to produce milk increases.
5. Estimates the value of heifers on hand at half their mature value ($425.00).
6. Land which is left idle is assumed to be rented out for $65.00 per acre. This amount is added to the gross margin.

CHAPTER 4: DISCUSSION

4.1 Discussion Of The General Assumptions

As with all models, linear programming models incorporate a number of assumptions which in certain applications can cause problems in adequately representing reality. Major assumptions implicit in the basic LP models include: divisibility, proportionality, additivity (independence) and deterministic, i.e. nonstochastic, parameters.

Divisibility means all decision variables, such as quantity of corn silage fed per cow per year and replacements raised per year, can be divided into any fraction. The linearity assumption of linear programming implies that each stated activity can be divided into any fraction having the same proportionate resource demand and gross margin.

Proportionality means that for any given decision variable, x_j, its contribution to cost (or income) is $c_j x_j$ and it's contribution to the i^{th} constraint is $a_{ij} x_j$. If x_j is doubled, so is it's contribution to cost and to each of the constraints. There are important examples where proportionality may not be applicable. The nutritional value of some feedstuffs may be greater when fed in small amounts than at higher amounts. Labor requirements aren't proportional with the number of cows and young stock at the farm but must be handled either through an adjustment in the RHS(b_i's) quantities or in a fixed account vector.

Additivity means the resource demands and gross margin per unit of an activity are independent of the level of that activity and of any other activity. The presence of associative effects would violate this assumption. The cows' milk production not only in the early period of lactation but also in subsequent phases is not independent of the amount of nutrients fed in the early phase of lactation. The model is based upon a total production cycle of good nutrition.

Nonstochastic means that the parameters are known with certainty. The value of the parameters depends on characteristics of the farm and on management skills of the operator. Since the variation in both is wide, parameters are seldom known with certainty.

This particular model of a dairy farm in south-eastern Minnesota incorporates a number of assumptions besides the general ones, which might not be consistent with reality. The technologies used may differ from technologies currently used on many south-eastern Minnesota farms. The dairy herd is bigger. Better management conditions on our model farm might result in shorter calving intervals, fewer calf losses, lower age at first calving, higher nutrient values of own forages, less harvesting, storage and feeding losses, etc. The average results of these management factors might be better on farms with the characteristics of our model farm.

Storage of corn silage in a horizontal silo might result in a decrease in milk production. This could cause a reduction in corn silage quality. Researchers at Michigan State University found a decrease in milk production of 0.6 percent when alfalfa haylage was stored in a horizontal silo under good management conditions (Rotz, et. al., 1989). In our model, the quality of the forages as feed doesn't depend on whether it is stored in upright or horizontal silos.

Important assumptions with respect to nutrients required for maintenance and milk production and the number of young stock in the herd are discussed in section 4.2 and 4.3.

4.2 Nutrient Requirements For Maintenance And Milk Production

Tables B1, B2 and B3 in Appendix B show the calculated and balanced rations of the alternative plans. A balanced ration has all the nutrients the animal needs in the right proportions and amounts (Gillespie, 1983).

Nutrient requirements vary with the stage of lactation and gestation. Figure 1 in Appendix C illustrates four distinct feeding phases based upon the shape and relationship of curves for milk production, fat percentage, dry matter intake and body weight change during lactation:

1. Early lactation: 0 to 70 days (peak milk production) after calving (postpartum);
2. peak dry matter intake: 70 to 140 days (declining milk production);
3. mid- and late-lactation: 140 to 305;
4. dry period: 45 to 60 days before the next lactation.

In the early lactation phase, milk production increases rapidly. Feed intake does not keep pace with nutrient, especially energy, needs for milk production. Protein is a critical nutrient during early lactation because it helps stimulate feed intake and permits efficient use of mobilized body tissue for milk production. A nutrient shortfall in the early lactation phase will result in a reduction in performance in early lactation as well as in subsequent phases. If the shortfall is serious, it may significantly increase re-breeding difficulties. In the second phase, feed intake is near maximum and can supply nutrient needs. In the mid- to late-lactation phase, milk production is declining, and nutrient intake can easily meet or exceed requirements (Linn, et al, 1989).

Following the guidelines found in Feeding The Dairy Herd (Linn, et al, 1989), rations may need to contain 19 percent or more crude protein to meet requirements in early lactation. This need decreases to 13 percent in late lactation. The rapid increase in milk production in early lactation requires 0.78 Mcal per pound of DM or above. Net energy needs decrease to 0.7 Mcal per pound of DM in late lactation and 0.6 Mcal per pound during the dry phase. Fiber content of the ration should be at a minimum of 18 percent acid detergent fiber (ADF) in the DM during early lactation, increasing to 21 percent or greater in late lactation. Grain should be fed according to milk production. The grain to milk ratio for cows producing 18,000 lbs per year is commonly about 1:3 on a dry matter basis. The proportion of concentrates in the ration increases as the level of production increases. Forages are bulky and do not supply sufficient energy for high production levels. There is a limit to the level of dry matter a cow can realistically consume.

From Tables B1 and B3 in Appendix B, it is calculated that the crude protein content of the rations in all plans is about 14 percent on a dry matter basis. Net energy of the rations is about .7 MCal per pound of DM (Table B2 and B3). Total digestible nutrients (TDN), another method of expressing the energy content of feeds or the energy requirements of cattle, is about 65.8 percent on a DM basis. Fiber content is about 30 percent ADF in the DM. The grain to milk ratio is about 1:22 in the basic plan, plan 2 and plan 3.

A close look at the rations results in the conclusion that the feed requirements in our model needs further modification. The amount of crude protein (CP) and net energy (NEl) is now calculated based on the recommendations found in Linn, et. al. The dry matter intake level depends on the protein and net energy needs in the feeding phases. Table 4.4 lists nutrient requirements and maximum dry matter intake for cows in the various feeding phases. Less land is required to supply the nutrients specified in this model than what is reported from other sources. This model provides forage for a 100 cow herd off of 160 acres or less. Farmer experience indicates that it takes at least 200 acres on most farms.

Table 4.1: Nutrient requirements and dry matter intake for cows producing

	Feeding Phases			
	Early Lac.	Peak	Mid-to Late Lac.	Dry Period
Days	70	70	195	60
Milk per day (lbs)	60	70	53.33	
Crude Protein (cwt)	4.201	4.798	10.596	1.572
Net Energy for (lactation (CMcal)	19.908	22.106	51.374	7.500
Maximum dry matter intake (lbs)	2211	2665	6836	1250
Maximum dry matter intake (%BW[1])	2.4	2.0	2.7	1.6
Maximum dry matter protein (%DM[1])	19	18	15.5	12.6
Net Energy (Mcal/lbs DM)	0.90	0.83	0.75	0.6

[1] Body-weight of cows is 1,300 lbs.

The maximum dry matter intake in Table 4.1 seems rather low. This is in part caused by calculating the maximum dry matter intake as a percentage of a constant bodyweight. In Figure 1, Appendix C, it can be found that the cows' body weight is not constant. In the early phase of lactation, it is almost impossible for a high producing cow to get enough energy from the feed it consumes. Thus, body tissue is used in the production of milk. Later in lactation, when nutrient requirements for milk production are not so great, lost tissue is regained (Feitshans, 1980). Expected dry matter intake is higher for cows in early lactation (Linn, et. al., 1989).

Solving the model for the nutrient requirements given in Table 4.1 results in the ration given in Table 4.2.

Table 4.2: Balanced feeding ration for a 100 cow herd at 18,000 lbs per year using revised nutrient requirements.

	Nutrients CP (cwt)	NEl ((Mcal)	Maximum Dry Matter (cwt)
Requirements	1,956	9,324	11,980
HM Shelled Corn	473 (24%)	4,349 (47%)	4,727 (39%)
Corn silage	350 (18%)	1,954 (21%)	2,916 (24%)
Soybean meal	601 (31%)	1,048 (11%)	1,205 (10%)
Alfalfa hay	463 (24%)	1,714 (18%)	2,721 (23%)
Alfalfa haylage	70 (4%)	259 (3%)	412 (3%)
Total	1,957	9,324	11,981

This ration meets the nutrient requirements given in Table 4.4. Fiber content of the ration is about 18 percent ADF in dry matter. This might be a little low. The grain to milk ratio is about 1:2.8 on a dry matter basis.

The cropping program now consists of 55 acres of high moisture shelled corn and soybeans in a corn on soybean rotation, 3 acres of high moisture shelled corn on 3 acres of last year's alfalfa ground, 18 acres of corn silage on 18 acres of last year's alfalfa ground, 21 acres of alfalfa with a companion crop of oats which is harvested as oat silage and 63 acres of alfalfa providing 4.5 dry matter tons per acre of alfalfa per year in three cuttings. In Table 4.3 the cash receipts and the cash expenses of the model based on the new nutrient requirements are given (Revised Basic Plan). The gross margin of the model using the new nutrient requirements is $142,739. It is now assumed that the shelled corn will be custom dried and handled as dry shell corn instead. A $.25 per bushel custom drying charge is deducted from the gross margin. The amount and value of purchased feed increases. The new gross margin is $11,368 lower than the gross margin in the model with the original data (Table 4.3).

Table 4.3: Cash receipts less cash expenses of the basic plan using original nutrient requirements compared to a revised basic plan using changed new nutrient requirements. In plan 2A no upright silos are used, plan and nutrient requirements are adjusted in the revised basic plan.

	Basic Plan		Revised Basic Plan		Plan 2A	
	Quantity	Value	Quantity	Value	Quantity	Value
<u>Cash Receipts</u>						
Milk sales (cwt)	17,647	176,470	17,669	176,688	17,669	176,688
Bull calves sold (hd)	44	2,640	44	2,640	44	2,640
Replacements sold (hd)	5	4,000	5	4,000	5	4,000
Soybeans sold (bu)	1,035	5,123	1,241	6,143	1,241	6,143
Total cash receipts		188,233		189,471		189,471
<u>Cash Expenses</u>						
Cows (hd)	100	11,270	100	11,270	100	11,270
Replacement heifers (hd)	34	2,619	34	2,619	34	2,619
Crop production:						
HM Shelled corn (DMT)	0	0	133	3,451	161	3,980
Corn silage (DMT)	492	5,820	170	1,968	109	1,211
Alfalfa hay + haylage (DMT)	351	2,954	351	2,429	351	2,321
Oatlage (DMT)	38	902	38	888	38	888
Pasture (DMT)	26	115	26	115	26	115
Total (DMT)	907	9,791	718	8,851	685	8,515
Purchased feed:						
HM Shelled corn (bu)	0	0	6,160	11,042	0	0
Ear corn (bu)	1,373	2,747	0	0	6,042	12,084
Soybean meal (DM cwt)	143	1,111	1,205	9,336	1,358	10,527
Total (DMT)	48	3,858	206	20,378	246	22,611
Cash crop production:						
Soybean (DMT)	28	1,417	34	1,651	34	1,651
Bedding:						
purchased straw (tons)	113	3,965	0	0	0	0
Corn stalks (tons)	0	0	113	335	113	335
Hired labor (hr)	172	1,206	223	1,628	273	1,912
Total cash expenses		34,126		45,326		47,211
Gross Margin		154,107		142,739		140,558

To show the impact of the new nutrient requirements on the ranking of alternative plans, Table 4.3 also presents the gross margin of plan 2. Using horizontal silos instead of upright silos results in a gross margin of $140,558.

The new required milk price to cover all costs, given higher nutrient requirements, is calculated for the revised basic plan. The increase in nutrient requirements raises the required milk price to cover all costs to $15.39 per hundred weight. This is an increase of $0.77 per hundred weight compared to the required milk price using the original assumption and data. This is a result of the lower gross margins and higher annual machinery overhead costs. Using horizontal silos (Plan 2) results in this case in a required milk price to cover all costs to $15.11 per hundred weight.

The result of the increase in nutrient requirements for cows is a significant increase in required milk price to cover all costs. Significant changes in the relative profitability of alternative plans as discussed in Chapter 3 is unlikely. Plan 5 needs another definition since the farm now automatically raises its own bedding.

4.3 The Number Of Young Stock In The Herd

The model assumes an 88 percent calving percentage for the herd. The annual number of calves from the 100 cows would be 44 bull calves and 44 heifer calves. The real number of calves born in a 100 cow herd is higher under normal management conditions. The potential number of calves in the herd depends not only on the number of cows, but also on the number of first-calf heifers.

We assume that 28 percent of the cows in the herd are culled annually due to low production, chronic mastitis, repeat breeding, excessive age, etc. An additional two percent of the cows die annually and must be replaced. The annual herd turnover rate is 30 percent. The calving percentage of the culled cows is 50 percent. This adds 15 calves annually beyond the calving of the remaining herd.

The annual number of calves of the remaining 70 cows in second or later lactation depends on the calving interval. Extended calving intervals result in fewer calves born each year. Each month the calving interval is extended beyond 12 months resulting in an 8 percent reduction in the number of calves born in the herd each year (Conlin, 1978). Cows in our herd have a 13-month calving interval. The 70-cow herd produces 64.4 calves annually. Together with the calf crop from the culled cows, a total calf crop of 79.4 calves, evenly divided between heifers and bulls, is expected.

The number of calves coming from first-calf heifers depends on the amount of replacements raised. We assume that the replacements come into the milking herd or are sold after calving. A mortality rate of 15 percent for calves from birth to 5 days of age is assumed. The modified part of the model can be found in Appendix D.

The increase in the number of youngstock results in a new gross margin of $147,472. This is $4,733 higher than the gross margin in the new basic plan in Table 4.3. The higher annual overhead costs doesn't offset the higher in gross margin. The minimum milk price to cover all costs is now $15.32.

CHAPTER 5: SUMMARY AND CONCLUSIONS

The performance of the Upper Midwest dairy sector with respect to such important management factors as production per cow, herd size, debt level and capital investment is below the U.S. average. In 1988 production per cow was 219 pounds per cow below the U.S. average. In 1987, only 5 percent of all dairy farms in the Upper Midwest had more than 100 cows as compared to the U.S. average of 10.1 percent. In 1985, during the farm crisis, the average percent in debt for Upper Midwestern dairy farms was 0.667 while U.S. average percent in debt for dairy farms was 0.37. The average milk price received is also less than average in the U.S. The difference in milk price received for all milk was $0.49 per hundredweight in 1988.

In part as a result of differences in performance or in management factors and in milk price, the economic performance is also below U.S. averages. If current trends continue, a further shift in milk production to the Northwest, Southwest and Southeast regions is likely.

Management is described as an important factor with respect to a farm's profitability. The decision making process whereby limited resources are allocated to a number of production alternatives causes great differences in the profitability between farms in the same region, even if similar amounts of land and capital are available.

An LP model was used to compare the potential profitability of alternative farm plans for the Upper Midwest. The characteristics of the modeled dairy farm are: two families, milking 100 cows, producing 18,000 pounds of milk per cow per year in a free stall facility. The milking facility consists of a double 8 herringbone with full mechanization. The dairy farm has 183 acres of land. In the basic plan the required milk price to cover all costs is $14.65, given the assumed rates for capital recovery.

Table 5.1 compares the profitability of the alternative plans in terms of the required milk price to cover all costs and the change in farm income. Using horizontal silos for storage of corn silage and oat silage results in the greatest positive change in farm income. A plan requiring production of all bedding resulted in the greatest negative change in farm income.

The general assumptions of any LP model are not consistent with the dynamics on a dairy farm. Consequently, using an LP model to analyze the profitability of alternative plans cannot be more than a first approximation.

Assumptions made in the model with respect to the nutrient requirements for the cows results in an important underestimation of the required milk price to cover all costs. Modification of these requirements results in an increase of the required milk price with $0.77 per hundred weight to $15.39. After modifying the number of calves in the herd, the new milk price required to cover all costs is $15.32.

Assumptions made with respect to the nutrient requirements are of great influence on the required milk price to cover all costs. The capital stock and flow costs and the reservation rates of returns they imply are not covered at current milk prices. Either higher milk production rates or more prudent investments would be required to make dairy expansion feasible in the case of the model farm. Further analysis of alternative strategies are needed to explore such alternatives. These should also include further examinations of labor productivity.

Table 5.1: Required milk price to cover all costs for alternative plans related change in cash farm income.

	Basic plan	Hori-zontal silos	Square baler	No cash crops	Raising own bedding	Buying replac-ements
Req. milk price ($/cwt)	14.65	14.37	14.49	14.59	15.06	14.95
Change in cash farm income ($)	-	4,941	2,824	1,059	-7,233	-5,294

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APPENDIX A

Table A1: A Descriptive List of Model Activities

Activity Column	Activity Description
C 1	An activity which milks one cow.
C 2	An activity which raises a replacement heifer.
C 3	Grows and harvests one acre of high moisture shelled corn in a corn on corn rotation.
C 4	Grows and harvests one acre of ear corn in a corn on corn rotation. Corn may be harvested as either high moisture ear corn or dry ear corn.
C 5	Grows and harvests one acre of corn silage in a corn on corn rotation.
C 6	Grows and harvests one half acre of high moisture shelled corn and one half acre of soybeans in a corn on soybean rotation.
C 7	Grows and harvests one half acre of ear corn and one half acre of soybeans in a corn on soybean rotation. Corn may be harvested as either high moisture ear corn or dry ear corn.
C 8	Grows one half acre of corn silage and on half acre of soybeans in a corn on soybeans rotation.
C 9	Grows high moisture shelled corn on an acre of last year's alfalfa ground.
C 10	Grows ear corn on an acre of last year's alfalfa ground. Corn may be harvested as either high moisture ear corn or dry ear corn.
C 11	Grows corn silage on an acre of last year's alfalfa ground.
C 12	Square bales one ton of corn stalks for use as bedding.
C 13	Establishes on acre of alfalfa with a companion crop of oats which is harvested as grain.
C 14	Establishes one acre of alfalfa with a companion crop of oats which is harvested as oat silage.
C 15	Establishes one acre of alfalfa in a direct seeding using herbicides for weed control.
C 16	One acre of alfalfa providing 4.5 dry matter tons of alfalfa per year in three cuttings.
C 17	An activity which uses a square (conventional) baler to harvest a dry matter ton of first cutting alfalfa.
C 18	An activity which uses a large round baler to harvest one dry matter ton of first cutting alfalfa.
C 19	An activity which uses a square baler to harvest a dry matter ton of second or third cutting alfalfa.
C 20	An activity which uses a large round baler to harvest one dry matter ton of second or third cutting of alfalfa.
C 21	Transfers from harvest to storage one dry matter hundredweight of high moisture shelled corn which was produced on the farm.
C 22	Places one dry matter hundredweight of high moisture shelled corn into an upright concrete stave silo.

Table A1: A Descriptive List of Model Activities (Continued)

Activity Column	Activity Description
C 23	Places one dry matter hundredweight of high moisture shelled corn into a horizontal (bunker) silo.
C 24	Stores one dry matter hundredweight of ear corn.
C 25	Transfers from harvest to storage one dry matter hundredweight of high moisture ear corn which was produced on the farm.
C 26	Places one dry matter hundredweight of high moisture ear corn into an upright concrete stave silo.
C 27	Places one dry matter hundredweight of high moisture ear corn into a horizontal silo.
C 28	Stores one dry matter ton of corn silage in an upright concrete stave silo with added urea.
C 29	Stores one dry matter ton of corn silage in a horizontal silo with added urea.
C 30	Stores a hundredweight of soybeans for use as animal feed.
C 31	Stores a dry matter ton of square baled alfalfa hay in a hay shed.
C 32	Stores a dry matter ton of large round baled alfalfa hay in a hay shed.
C 33	Harvests and stores a dry matter ton of first cutting alfalfa haylage in an upright concrete stave silo.
C 34	Harvests and stores a dry matter ton of first cutting alfalfa haylage in a horizontal silo.
C 35	Harvests and stores a dry matter ton of second or third cutting alfalfa haylage in an upright concrete stave silo.
C 36	Harvests and stores a dry matter ton of second and third cutting alfalfa haylage in a horizontal silo.
C 37	Stores a dry matter hundredweight of oats for use as animal feed.
C 38	Stores one dry matter ton of oat silage in an upright concrete stave silo.
C 39	Stores one dry matter ton of oat silage in a horizontal silo.
C 40	Feeds one dry matter hundredweight of shelled corn to cows.
C 41	Feeds one dry matter hundredweight of ear corn to cow.
C 42	Feeds one dry matter ton of corn silage with urea to cows.
C 43	Feeds one dry matter hundredweight of soybeans to cows.
C 44	Feeds one dry matter hundredweight of soybean meal to cows.
C 45	Feeds one dry matter ton of alfalfa hay to cows.
C 46	Feeds one dry matter ton of alfalfa haylage to cows.
C 47	Feeds one dry matter hundredweight of oats to cows.
C 48	Feeds one dry matter ton of oat silage to cows.
C 49	Feeds one dry matter hundredweight of shelled corn to replacement heifers.
C 50	Feeds one dry matter hundred weight of ear corn to replacement heifers.
C 51	Feeds one dry matter ton of corn silage to replacement heifers.

Table A1: A Descriptive List of Model Activities (Continued)

Activity Column	Activity Description
C 52	Feeds one dry matter hundredweight of soybeans to replacement heifers.
C 53	Feeds one dry matter hundredweight of soybean meal to replacement heifers.
C 54	Feeds one dry matter ton of alfalfa hay to replacement heifers.
C 55	Feeds one dry matter ton of alfalfa haylage to replacement heifers.
C 56	Feeds one dry matter hundredweight of oats to replacement heifers.
C 57	Feeds one dry matter ton of oat silage to replacement heifers.
C 58	Pastures replacement heifers on one acre of pasture.
C 59	Buys a replacement heifer.
C 60	Buys one bushel of dry shelled corn.
C 61	Buys and places into storage one bushel of high moisture shelled corn.
C 62	Buys one bushel of dry ear corn.
C 63	Buys and places into storage one bushel of high moisture ear corn.
C 64	Buys one ton of alfalfa hay.
C 65	Buys one hundredweight of soybean meal.
C 66	Buys one ton of straw for bedding.
C 67	Buys one hundredweight of elemental nitrogen for fertilizer.
C 68	Buys one hundredweight of phosphate for fertilizer.
C 69	Buys one hundredweight of potash for fertilizer.
C 70	Hires one hour of labor during the April 16 to May 15 period.
C 71	Hires one hour of labor during the May 16 to June 15 period.
C 72	Hires one hour of labor during the June 16 to August 31 period.
C 73	Hires one hour of labor during the September 1 to October 15 period.
C 74	Hires one hour of labor during the October 16 to November 15 period.
C 75	Sells one hundredweight of milk after hauling charges are deducted.
C 76	Sells one heifer calf at birth.
C 77	Sells one bull calf at birth.
C 78	Sells one raised replacement heifer.
C 79	Sells one bushel of high moisture corn directly from the field.
C 80	Sells one bushel of soybeans directly from the field.
C 81	Sells one ton of alfalfa from storage.
C 82	Sells one bushel of oats directly from the field.
C 83	Accounts for labor expended for the general operation of the farm.

APPENDIX A

Table A2: A Descriptive List of Model Constraints

Constraint Row	Constraint Description
R 1	Restricts milk sales to amount produced by dairy cows.
R 2	Restricts bull calf disposition to number produced.
R 3	Restricts heifer calf disposition to number produced.
R 4	Assures sufficient replacement heifers are obtained to maintain herd size.
R 5	Limits herd size to amount of space in the barn.
R 6	Limits number of replacement animals to amount of space in the barn.
R 7	Minimum hundredweights of crude protein needed by the cows.
R 8	Minimum net energy for lactation in hundred megacalories needed by the cows.
R 9	Maximum hundredweights of dry matter intake for cows.
R 10	Minimum crude protein required to raise replacement heifers.
R 11	Minimum net energy for maintenance and gain in hundred megacalories to raise replacement heifers.
R 12	Maximum hundredweights of dry matter intake for replacement heifers.
R 13	Limits pasture usage to acres available.
R 14	Limits acres of crop production to the amount available.
R 15	Restricts the total acres of alfalfa and corn which may be grown.
R 16	Restricts the total acres of row crops which may be grown.
R 17	Limits the acres of alfalfa to the amount seeded.
R 18	Limits the acres of crops grown after alfalfa to the number of acres of alfalfa plowed down.
R 19	Assures adequate nitrogen available to produce the stated crop yields.
R 20	Assures adequate phosphorous available to produce the stated crop yields.
R 21	Assures adequate potassium available to produce the stated crop yields.
R 22	Dry matter hundredweights of shelled corn standing in the field.
R 23	Dry matter hundredweights of ear corn standing in the field.
R 24	Dry matter tons of corn silage standing in the field.
R 25	Dry matter hundredweights of soybeans standing in the field.
R 26	Dry matter tons of first cutting alfalfa standing in the field.
R 27	Dry matter tons of second and third cutting alfalfa standing in the field.
R 28	Dry matter hundredweights of oats standing in the field.
R 29	Dry matter tons of oat silage standing in the field.
R 30	Tons of corn stalks available to bale for bedding.
R 31	Assures adequate bedding is available.

Table A2: A Descriptive List of Model Constraints (continued)

Constraint Row	Constraint Description
R 32	Transfers a dry matter hundredweight of high moisture shelled corn to storage.
R 33	Transfers a dry matter hundredweight of high moisture ear corn to storage.
R 34	Transfers a dry matter ton of small square baled alfalfa hay to storage.
R 35	Transfers a dry matter ton of large round baled hay to storage.
R 36	Transfers a dry matter hundredweight of shelled corn to feeding.
R 37	Transfers a dry matter hundredweight of ear corn to feeding.
R 38	Transfers a dry matter ton of corn silage to feeding.
R 39	Transfers a dry matter hundredweight of soybeans to feeding.
R 40	Transfers a dry matter hundredweight of soybean meal to feeding.
R 41	Transfers a dry matter ton of alfalfa hay to feeding.
R 42	Transfers a dry matter ton of alfalfa haylage to feeding.
R 43	Transfers a dry matter hundredweight of oats to feeding.
R 44	Transfers a dry matter ton of oat silage to feeding.
R 45	Limits hours of labor used during the April 16 to May 15 time period to the hours available.
R 46	Limits hours of labor used during the May 16 to June 15 time period to the hours available.
R 47	Limits hours of labor used during the June 16 to August 31 time period to the hours available.
R 48	Limits hours of labor used during the September 1 to October 15 time period to the hours available.
R 49	Limits hours of labor used during the October 16 to November 15 time period to the hours available.
R 50	Limits hours of labor used during the November 16 to April 15 time period to the hours available.
R 51	Limits hours of field time used during the April 16 to May 15 time period to the hours available.
R 52	Limits hours of field time used during the May 16 to June 15 time period to the hours available.
R 53	Limits hours of field time used during the June 16 to August 31 time period to the hours available.
R 54	Limits hours of field time used during the September 1 to October 15 time period to the hours available.
R 55	Limits hours of field time used during the October 16 to November 15 time period to the hours available.
R 56	Forces the usage of labor and capital for general farm operation.

APPENDIX B

Table B1: Feed rations delivering the amount of crude protein required for maintenance and milk production.

		Alternative Plans				
	Basis	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
Corn silage (cwt)	1,038 (57%)[1]	934 (51%)	1,054 (58%)	1,234 (68%)	1,066 (58%)	1,099 (60%)
Alfalfa hay (cwt)	474 (26%)	474 (26%)	383 (21%)	438 (24%)	163 (9%)	375 (21%)
Alfalfa haylage (cwt)	166 (9%)	230 (13%)	249 (14%)	89 (5%)	179 (10%)	414 (23%)
Oatlage (cwt)	76 (4%)	76 (4%)	75 (4%)	64 (4%)	- -	- -
Ear corn (cwt)	72 (4%)	111 (6%)	66 (4%)	- -	79 (4%)	19 (1%)
Oats grain (cwt)	- -	- -	- -	- -	146 (8%)	- -
Soybean meal (cwt)	- -	- -	- -	- -	193 (11%)	- -
Total (cwt)	1,826	1,825	1,827	1,825	1,826	1,907

[1] Percentage of total

Table B2: Feed rations delivering the amount of net energy for lactation (NEl) in Cmcal[1] required for maintenance and milk production.

	Basis	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
		Alternative Plans				
Corn silage (Cmcal)	5,759	5,184	5,846	6,846	5,913	6,097
	(64%)[2]	(58%)	(65%)	(76%)	(66%)	(68%)
Alfalfa hay (Cmcal)	1,626	1,626	1,313	1,503	557	1,287
	(18%)	(18%)	(15%)	(17%)	(6%)	(14%)
Alfalfa haylage (Cmcal)	569	788	852	307	615	1,419
	(6%)	(9%)	(10%)	(3%)	(7%)	(16%)
Oatlage (Cmcal)	378	378	372	320	-	-
	(4%)	(4%)	(4%)	(4%)	-	-
Ear corn (Cmcal)	642	998	592	-	713	172
	(7%)	(11%)	(7%)	-	(8%)	(2%)
Oats grain (Cmcal)	-	-	-	-	849	-
	-	-	-	-	(10%)	-
Soybean meal (Cmcal)	-	-	-	-	328	-
	-	-	-	-	(4%)	-
Total (Cmcal)	8,974	8,974	8,975	8,976	8,975	8,975

1. Cmcal = 100 mcal
2. Percentage of total

Table B3: Dry matter intake (cwt) of feed rations

	Basis	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
		Alternative Plans				
Corn silage (cwt)	7,986	7,188	8,106	9,492	8,198	8,454
	(61%)[1]	(55%)	(62%)	(73%)	(66%)	(63%)
Alfalfa hay (cwt)	2,758	2,758	2,226	2,548	945	2,182
	(21%)	(21%)	(17%)	(20%)	(8%)	(16%)
Alfalfa haylage (cwt)	964	1,337	1,445	520	1,042	2,406
	(7%)	(10%)	(11%)	(4%)	(8%)	(18%)
Oatlage (cwt)	595	559	586	503	-	-
	(5%)	(4%)	(5%)	(4%)	-	-
Ear corn (cwt)	769	1,194	708	-	854	206
	(6%)	(9%)	(5%)	-	(7%)	(16%)
Oats grain (cwt)	-	-	-	-	1,075	-
	-	-	-	-	(9%)	-
Soybean meal (cwt)	-	-	-	-	389	-
	-	-	-	-	(3%)	-
Total (cwt)	13,072	13,073	13,072	13,063	12,504	13,248

[1] Percentage of total

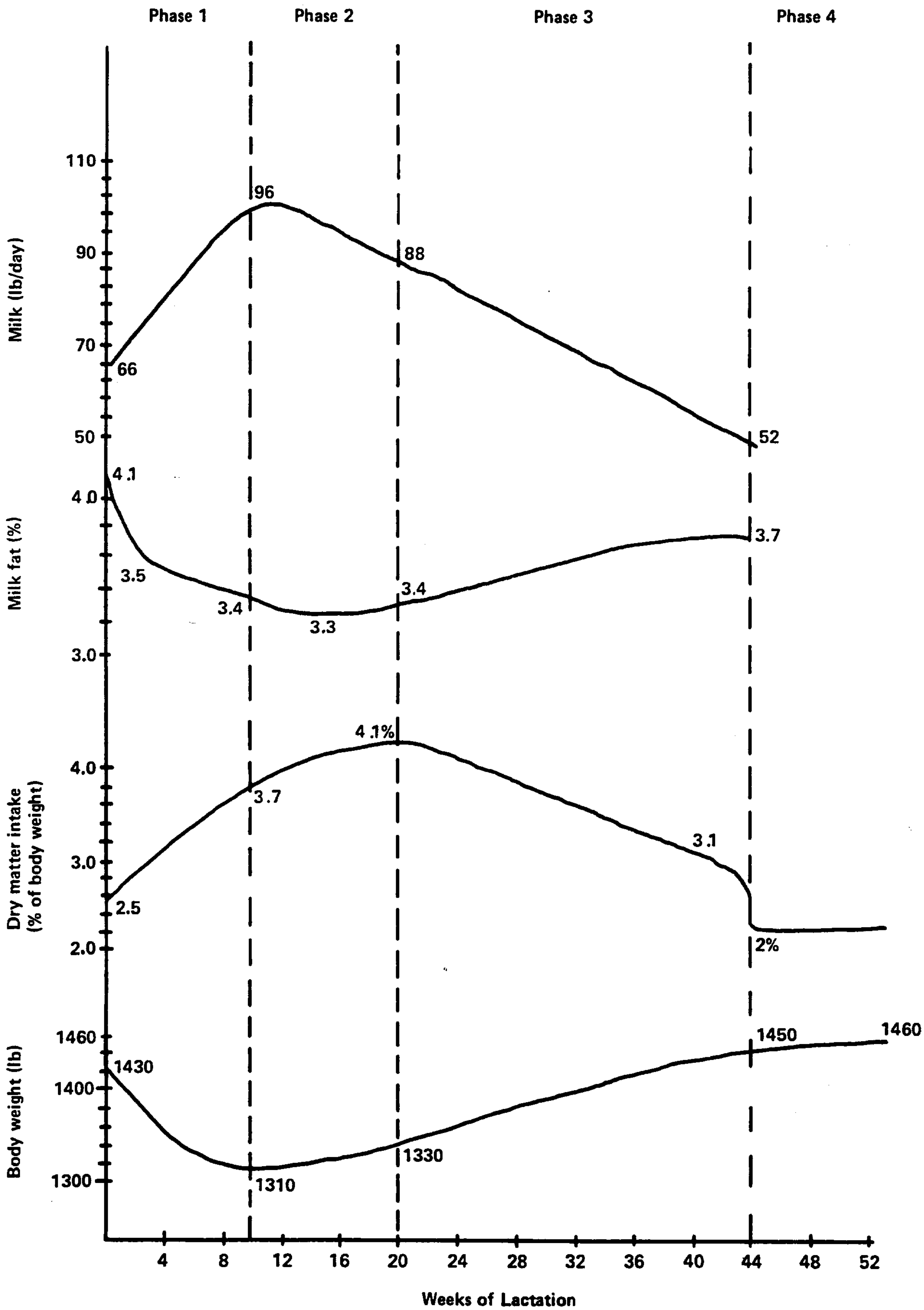

Figure 6. Lactation cycle phases with corresponding changes in milk production, milk fat percentage, dry matter intake, and body weight.

APPENDIX D

Table 1: Modified Part of the Model - Initial Tableau Illustrating the nutritional and Other Control Characteristics of the Dairy Enterprise Component

Row	Description	Milk Cow Cow-Year	Lac. Per. 1 Cow-Year	Lac. Per. 2 Cow-Year	Lac. Per. 3 Cow-Year	Dry Period Cow-Year	First Calf Heifer Head	Raise Replace-ment Head
1.	Milk Cwt Control	-	-42,000	-49,000	-104,000	-	-	-
2.	Couple 1-2	-	-1,000	1,000	-	-	-	-
3.	Couple 2-3	-	-	-1,000	1,000	-	-	-
4.	Couple 3-4	-	-	-	-1,000	1,000	-	-
5.	Couple 4-1	-	1,000	-	-	-1,000	-	-
6.	Couple Cows	-1,000	0.192	0.192	0.534	0.164	-	-
7.	Bull Calf Head Control	-0.397	-	-	-	-	-0.425	-
8.	Hfr Calf Head Control	-0.397	-	-	-	-	-0.425	1,300
9.	Rplmt Head Control	0.300	-	-	-	-	-1,000	-
10.	First Calf Head Control	-	-	-	-	-	1,000	-1,000
11.	Cow Barnspace Stall	-	0.192	0.192	0.534	0.164	-	-
12.	Yngstk Space Head	-	-	-	-	-	-	2,250
13.	Minimum CP Cwt Cow	-	4,201	4,798	10,596	1,572	-	-
14.	Minimum NE1 Cmcal Cow	-	19,908	22,106	51,374	7,5000	-	-
15.	Maximum DM1 Cwt Cow	-	-22,113	-26,654	-68,359	-12,500	-	-